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FOURTH EDITION. Enlarged.

Meteorology for Masters and Mates

BEING

QUESTIONS and ANSWERS

Based on the Information contained in the "Barometer Manual" and "Seaman's Handbook on Meteorology"

ARRANGED BY

CAPTAIN CHARLES H. BROWN,

Superintendent, School of Navigation, The Royal Technical College, Glasgow

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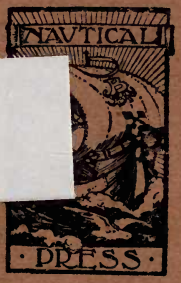
With B.O.T. Examination Papers.



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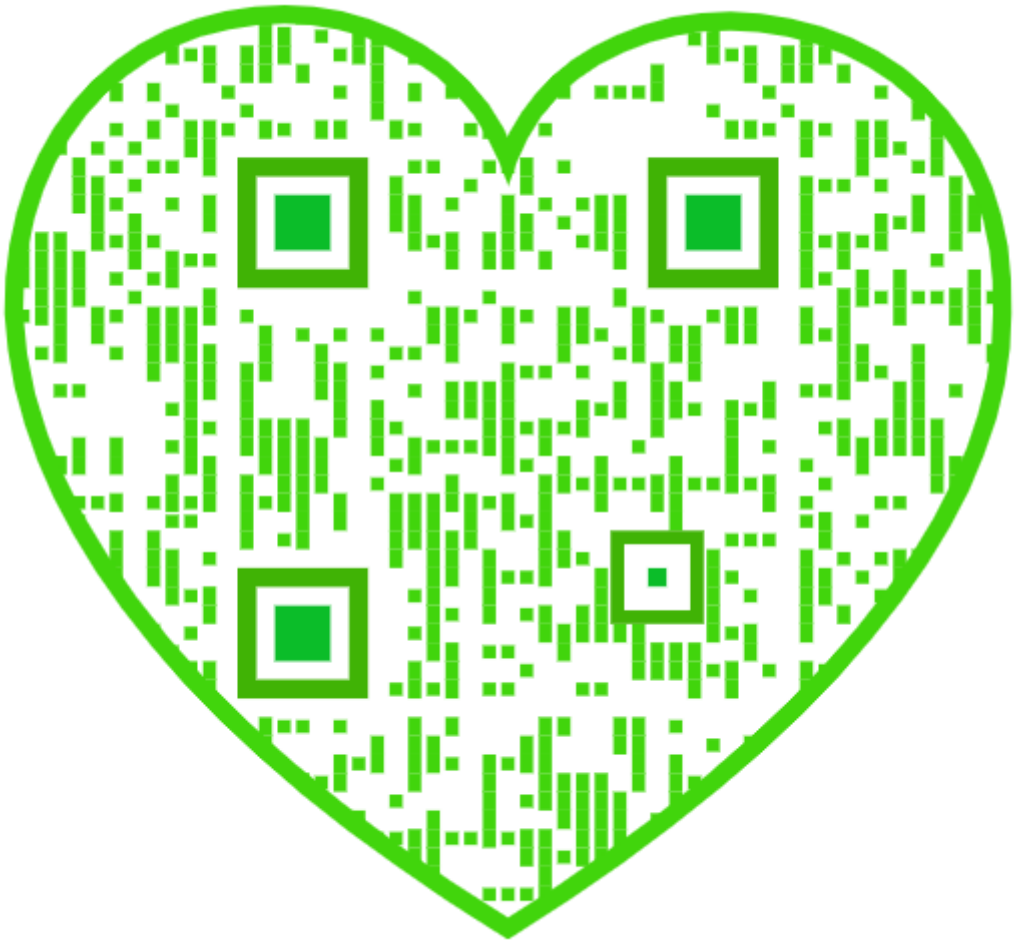

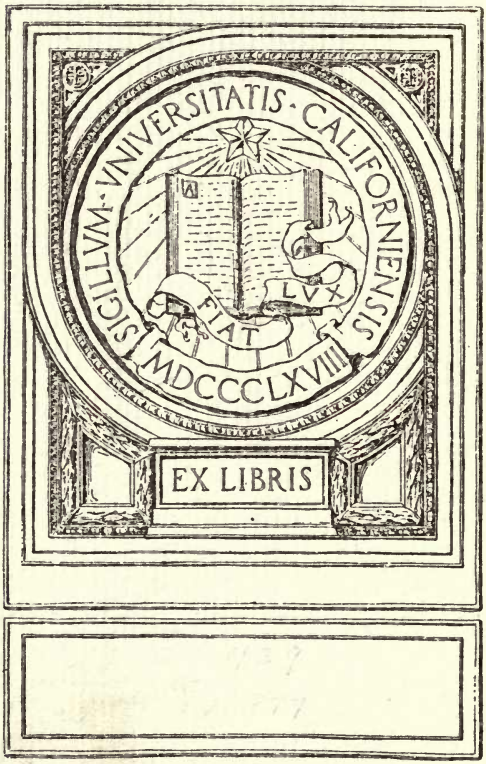
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INTRODUCTION.

A PAPER containing six questions on Meteorology is now set at the Examination for Masters and Mates, the text books recommended by the Marine Department, Board of Trade, being the *Barometer Manual for the use of Seamen* (eighth edition), and the *Seaman's Handbook on Meteorology* (second edition), both of which are official publications issued by the Meteorological Office.

Many students seem to find difficulty in distinguishing the essential facts from the illustrative matter given in these text books, so if the following questions and answers, based on the authoritative information contained therein, stimulates such students to a closer reading and a better understanding of the subject, their purpose will be attained.

Part I. deals with the information contained in the *Barometer Manual*, and Part II. with the information contained in the *Seaman's Handbook*, the questions being arranged in the consecutive order of the chapters, so that the student may test his knowledge as he proceeds methodically through the text books.

The questions on Meteorological Instruments have been grouped together at the beginning for the convenience of candidates for a second mate's certificate, who are expected to have a knowledge of the construction, use, and principle of such instruments.

The attention of students is specially directed to the questions that have been set at the Board of Trade Examinations, and which are given at the end of the book.

GLASGOW, *March*, 1917.

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Meteorology for Masters and Mates.

PART I.

METEOROLOGICAL INSTRUMENTS.

"Barometer Manual" Chapter I., and "Seaman's Handbook" Chapter XI.

Questions marked * have been set at the Examinations.

*** 1. Describe the mercurial barometer and the principle on which it works.**

The barometer consists of a glass tube about 32 inches in length, closed at one end and filled with mercury. The tube is then inverted and its lower end immersed in a cistern containing mercury. The column of mercury remains stationary in the tube at a height corresponding to the pressure exerted by the atmosphere on the surface of the mercury in the cistern. The column lengthens when the pressure is increased and shortens when the pressure is diminished, thus the weight of the column exactly balances the pressure of the atmosphere. The height of the top of the column above the surface of the mercury in the cistern is measured by means of a scale graduated in inches or millibars or both. The space between the mercury and the top of the tube is called the Torricellian vacuum.

2. What analogy exists between the action of a pump and the action of a barometer?

When the pump is at rest the atmospheric pressure in the chamber is equal to the pressure on the surface of

the water in the well. When the pump is worked, a partial vacuum is created in the chamber, thus diminishing the pressure, so that the relatively greater pressure exerted on the surface of the water in the well raises the water into the pump chamber.

In like manner, the pressure having been removed from the inside of the tube of the barometer by expelling the air, the pressure of the atmosphere on the surface of the mercury in the cistern forces the mercury up the tube, until the weight of the column is equal to that pressure.

A water barometer would require a tube about 33 feet in length, but mercury, being $13\frac{1}{2}$ times heavier than water, only requires a tube about 32 inches in length.

3. What is meant by "pumping," and what modification in the construction of marine barometers is adopted to reduce the pumping?

The rising and falling of the mercury caused by the heaving of the ship at sea, or the rocking of the instrument. Pumping is reduced by contracting the bore of the tube and also by slinging the barometer in gimbals.

4. What precautions should be observed when taking down a barometer and packing it for transport?

Unship it from the bracket and handle it carefully. The instrument should be brought into a horizontal position very gradually in order to allow the mercury to flow gently to the top of the tube. Put the barometer in its box and use soft packing, avoid jars and concussion, and carry the box horizontally with cistern end tilted up slightly. If sending by post or rail, put the label on the end next to the cistern, and mark it boldy "scientific instruments—glass—fragile—keep flat or this end up."

5. What might happen if a mercurial barometer were brought quickly from an upright to a horizontal position?

There being no air in the tube to act as a cushion, the weight of the mercury would probably break the glass.

6. Explain the symbols C.G.S.

Centimetre—gramme—second, the units used in physical science of which meteorology forms a part.

Centimetre is the hundredth part of a metre, the unit of length.

Gramme is the metric unit of mass.

Second is the universal unit of time.

7. What is a millibar?

The unit in the C.G.S. system adopted by meteorologists to express the pressure of the atmosphere. It is approximately the thousandth part of the average pressure of the atmosphere at sea level.

***8. What is the average pressure at sea level?**

14½ lbs. per square inch = 1000 millibars = 29·5 inches of mercury.

9. Describe the principle of the vernier.

A sliding scale by which more accurate readings of a fixed scale may be obtained. The principle of its construction is, that a given length of vernier, equal to a certain number of divisions of the fixed scale, is divided into one more or one less than that number of divisions.

The inch vernier of the marine barometer is usually equal in length to 9 divisions of the fixed scale and divided into 10 equal parts, the degree of accuracy thus obtained being ·005 of an inch.

The millibar vernier is equal to 39 divisions of the

fixed scale, but instead of being divided into 40 parts, the vernier is divided into 10 equal parts, thus giving a wider spacing of the divisions making, it easier to read and without loss of accuracy, the nearest reading obtainable being one-tenth of a millibar.

*** 10. Describe the corrections applied to a reading of the barometer and why they are necessary.**

Corrections for latitude, temperature and height above sea level are necessary in order to reduce the observation to a common standard for the purpose of comparison with the readings got from other barometers.

The standard latitude is 45°, this correction is necessary because the force of gravity is greater at the poles than at the equator, due to the polar diameter of the earth being shorter than the equatorial diameter.

The standard height is sea level, the correction being about one-tenth of an inch for every hundred feet, and is due to the atmospheric pressure decreasing with the height.

The standard temperature is 32° Fahr.; this correction is necessary because the column of mercury lengthens and shortens with heat and cold.

The value of these several corrections may be found in the *Barometer Manual.*

11. Describe the errors of capillarity and capacity.

Capillarity is caused by the frictional resistance between the mercury and the glass tube.

Capacity is due to the changes in the level of the mercury in the cistern as it rises and falls in the tube.

The scale of marine barometers is graduated to obviate the necessity of applying these two corrections.

12. What is meant by "standard temperature" marked on the brass plate of the barometers now issued by the Meteorological Office?

It is the temperature for which no correction is required at sea level in 45° latitude.

13. What is the fiducial temperature?

The temperature for which no correction is required in any other latitude. It is the standard temperature corrected for height and latitude.

14. How is the standard temperature corrected for height above sea level, and for latitude?

For height, by adding 1° A. (absolute) for every 5 feet the barometer is above sea level.

For latitude, by means of a table given in the *Barometer Manual.*

15. What correction is applied to the millibar scale to compensate for the difference between the fiducial temperature and the actual temperature as read from the attached thermometer?

One millibar for every 6° of difference between them. Subtract the correction when the attached thermometer reads higher, and add when it reads lower than the fiducial temperature.

*** 16. Describe an aneroid barometer. What corrections should be applied to the readings?**

It consists of a circular metallic chamber, partially exhausted of air and hermetically sealed. Variations in the pressure of the atmosphere produce changes in the volume of the chamber, and by an arrangement of levers and springs the motion thus imparted to the chamber is communicated to a hand which indicates the prevailing pressure.

It is not so reliable as the mercurial barometer, with which it should be frequently compared, nor is it possible to find with sufficient accuracy for scientific purposes the index error of the aneroid.

Aneroid readings require correction for height above sea level and index error, but not for temperature or latitude.

17. What further information is now being given on sea aneroid barometers?

The mean annual pressure for certain latitudes along the meridian of 30° west.

*** 18. Describe the barograph, its advantages and disadvantages.**

It consists of a series of vacuum metal boxes with elastic lids. The volume of the boxes changes with every variation of pressure in the same way as in the aneroid barometer. The expansion and contraction thus caused is communicated through a lever to a pen, which marks an ink trace on a paper. This paper is wound round a drum, which is rotated on a vertical axis by means of clock work, making a complete revolution in 7 days. The vertical lines printed on the barograph chart represents time, and the horizontal lines either inches or millibars. The pen moves up and down in response to changes of pressure, and the revolving drum imparts a horizontal motion to the paper which slips round under the pen.

The chief advantage lies in the fact that a continuous record of changes in pressure is presented in a graphic form, by means of which the history of the barometrical changes may be read at a glance, even slight fluctuations of pressure due to passing squalls being recorded.

Barograph readings are subject to the same correc-

tions as the aneroid, in addition to regulating its time at sea. The drum rotates at a uniform rate, while the ship time changes as she sails east or west; the drum should therefore be set to G.M.T., and the ship's longitude noted on the barograph chart.

19. Describe the construction and principle of the thermometer.

It consists of a glass tube of very small bore, having a bulb attached to one end, sealed at the other, and partially filled with mercury, or with spirits of wine if the instrument is required for very low temperatures.

Bodies expand with heat and contract with cold, and as mercury expands to a greater degree than glass we find the thin thread of mercury rising and falling in the tube as the temperature increases and decreases respectively.

*** 20. What are the two fixed points of the scales used in making thermometers and describe the graduations?**

The freezing point and boiling point of distilled water, when the barometrical pressure is 30·0 inches.

The space between these two points is divided into equal parts called degrees; the following systems of graduating have been adopted.

	Fahrenheit.	Centigrade.	Absolute.	Réaumur.
Boiling point - -	212°	100°	373°A	80°
Freezing point - -	32°	0°	273A	0°

The spacing of the degrees in the absolute scale is the same as in the centigrade.

21. How is the zero of the absolute scale determined?

It is based on the doctrine that gases contract on being cooled, their volume being diminished with loss of temperature. The zero represents the temperature at which a gas would have no volume, it would then cease to exert pressure, or be capable of developing energy.

22. Describe the thermograph, its advantages and disadvantages.

A self-recording thermometer, which gives a continuous record of temperature. The thermometer consists of a slightly curved metal tube filled with spirit, one end of the tube being fixed rigidly to the instrument, and the other end attached to the system of levers which actuates the recording pen.

The great advantage of the thermograph, especially if studied in connection with a barograph, is to demonstrate the close relationship which exists between the fluctuations of temperature and pressure.

Thermographs must be exposed out of doors and consequently the bearings require to be frequently oiled and examined. The instrument takes an appreciable time to alter in temperature, so it is apt to be sluggish when the changes of temperature are rapid.

23. What is the freezing point of mercury?

Minus 38° Fahrenheit.

24. Describe Mason's hygrometer, and the precautions to be taken with the instrument.

It consists of two ordinary thermometers placed side by side. One, called the wet bulb, has a piece of cambric tied to the bulb, and a few strands of cotton wick fastened to the cambric with their lower ends dipping into a cup of water. The cambric is thus kept

moist. The thermometers should be mounted in an open screen through which the air passes freely, and away from the effects of heated currents of air from cabins, etc.

Care should be taken to keep the cambric and wick clean, and the cup replenished with a supply of fresh water. Should the cambric and wick get wet with salt spray, they should be cleaned in fresh water, and care should be taken that no water is adhering to the dry bulb when the readings are noted.

*** 25. What is the hygrometer for and explain the principle of its working?**

It is for measuring the humidity of the air. When the air is dry, evaporation takes place and the water dries off the cambric, thus reducing the temperature of the wet bulb thermometer; when the air is moist there is less evaporation so that the difference between the wet and dry bulb readings is correspondingly less.

Consequently, in damp weather or when the air is saturated, there is little or no difference in the readings, but in dry weather at sea, the wet bulb may be as much as 10° lower than the dry bulb.

*** 26. Describe the principle and construction of the hydrometer.**

The principle depends on the fact that any floating body displaces a volume of the liquid in which it floats, equal in weight to the weight of the floating body itself.

It consists of a glass cylinder of sufficient volume to give adequate buoyancy, with a bulb on its lower end, filled with shot or mercury to act as ballast and to keep the instrument upright. A glass stem projects above the cylinders and contains the ivory scale, which is graduated downwards from 0 to 40, each division

indicating successive increases of density in the ratio of one in a thousand.

27. What unit is adopted for determining the specific gravity of liquids?

The density of pure distilled water at a temperature of 60° Fahr.

28. What is the range of density of sea water?

From the density of fresh water which is 0, to 40 which is found in some parts of the Suez Canal, but the average density of sea water is about 25.

29. How is the pressure and velocity of the wind ascertained?

By an anemometer.

Robinson's anemometer measures velocity only, but Dine's pressure tube records automatically and continuously fluctuations in the pressure of the wind as well as its velocity.

30. What method is adopted to record the force of the wind in a log book?

Beaufort's Scale of numbers 0 to 12, the figure 0 representing a calm, and 12 a hurricane in which the velocity of the wind is over 75 miles per hour.

31. How is the amount of rainfall measured?

By means of a rain gauge, consisting of a cylindrical funnel 5 inches in diameter, supported in an outer casing having an open top.

The rain falls into the funnel, is caught in a can, and measured in a glass graduated to indicate hundredths of an inch. One inch of rain in the glass is equal to 101 tons of rain per acre.

CHAPTER II.

BAROMETRICAL PRESSURE.

32. How often should the reading of the barometer be recorded at sea, and what information does a study of the readings convey to the seaman?

The readings should be recorded in the log book at regular intervals, at least every four hours.

The changes which take place from hour to hour and day to day in the barometrical pressure may give an indication of the approach of unsettled weather and of strong winds.

33. What influence has change of temperature on the barometrical pressure?

The air expands with heat and contracts with cold. The unequal expansion and contraction of the atmosphere thus created over different localities produces changes in its pressure.

34. What complication is introduced when comparing temperature with pressure as found at the earth's surface?

The pressure of the upper air may differ from the pressure of the lower strata, and as the barometer measures the average pressure of the whole height of the atmosphere, the distribution of the surface pressure cannot always be accounted for by the distribution of the surface temperature alone.

35. What method is adopted to show the distribution of air pressure over the globe?

By drawing lines on a chart through places having the

same barometric pressure. These lines are called isobars, and usually arrange themselves into irregularly shaped circular figures.

36. State what general conclusions may be drawn from a study of a pressure chart of the world? Give reasons.

(1) That barometrical pressure is greater in the relatively cold region than it is in the warm.

(2) That the pressure is greater over the land than over the sea during winter, the land being then colder than the sea. In summer the conditions are reversed, the sea is relatively colder than the land, and the pressure over the sea is then greater than over the land.

(3) During the northern summer the pressure is greater in the south hemisphere because it is then relatively colder than the north hemisphere, and conversely, during the southern summer when the sun has south declination the pressure is greater in the north hemisphere.

(4) That the pressure throughout the year is more uniform over the sea than over the land.

37. How may the seaman test the accuracy of a mercurial barometer at sea?

By applying to the reading of the barometer its index error, if any, and the corrections for height above sea level, temperature and latitude, then comparing the corrected reading with the average value given on the isobaric chart for the ship's position.

***38. Name the five great areas the earth's surface is divided into with regard to barometrical pressure.**

A belt of moderately low pressure over the equatorial regions, two high pressure belts, one north and one

south of the equatorial low, and two areas of lower pressure in the higher latitudes.

The zone of low pressure in the Southern Ocean forms a complete circuit of the globe.

39. Give the range of the mean barometric pressure in the British Isles in mid-winter and mid-summer.

Mid-winter—1009 mb. to 1016 mb., equal to 29·80 to 30·00 inches.

Mid-summer—1011 mb. to 1016 mb., equal to 29·85 to 30·00 inches.

***40. What sort of weather is experienced between the north-east and south-east trades and why?**

A region called the doldrums of calms and variable winds enlivened by occasional squalls of wind and torrential rain. There is great humidity. The differences in atmospheric pressure being small accounts for the light winds, and the humidity is caused by the great evaporation due to the sun being almost vertical over this region.

41. Account for the larger area occupied by the south-east trades than by the north-east trades.

Due probably to the greater expanse of water in the south hemisphere, thus producing a greater uniformity of temperature and pressure than prevails in the north hemisphere.

42. Are the equatorial limits of the trade winds constant throughout the year?

No. The equatorial limits move a few degrees north and south during the year. The doldrums are farthest north in July, August, and September, just after the sun has reached its greatest north declination, and extend

further south in February, March, April, when the sun has reached its greatest south declination.

*** 43. What causes the trade winds?**

The trade winds are caused by the air being impelled from the areas of high pressure towards the low pressure belt at the equator. The rotation of the earth deflects these air currents to the right hand in the north hemisphere and to the left hand in the south hemisphere, thereby producing the north-east and south-east trades respectively.

CHAPTER III.

VARIATIONS OF PRESSURE.

44. What is meant by the terms "high" and "low" barometer?

The barometer readings being considerably higher or lower than the average value for that time or place.

*** 45. Explain the terms periodical and non-periodical barometrical pressure.**

Periodical changes are those which occur at nearly regular intervals during the course of the day or year; non-periodical changes are irregular, and depart from average conditions, being immediately associated with changes of weather.

*** 46. When should the mean barometric pressure be recorded in the tropics, and why?**

At 1 o'clock and 7 o'clock a.m. and p.m. The barometer then indicates the mean between the maximum and minimum pressures for the day, the maximum occurring about 10 a.m. and 10 p.m., the minimum about 4 a.m. and 4 p.m.

47. What is the amount of diurnal range within the tropics?

2·4 mb. equal to ·07 inches.

48. Why is the daily range more marked in the tropics than in the temperate zones?

The daily oscillations of the mercury can seldom be recognised in the temperate zones because they are masked by the frequently recurring non-periodical

changes of pressure. In the tropics the daily range is seldom complicated by changes of weather. The range in sub-tropical regions is about ·02 inches.

*** 49. Of what special importance is a knowledge of the diurnal range to seamen?**

A departure from the regular daily fluctuations indicates a disturbance which may herald the approach of a cyclone, a typhoon, or a hurricane, these being the names given to a tropical revolving storm.

50. What is the average range of the barometer in the British Isles, and the average pressure?

Range 2·7 inches, the readings varying from 28·27 inches (957·4 mb.) to 30·97 inches (1048·8 mb.) The mean pressure is 29·62 inches (1003 mb.).

***50a. What governs the diurnal range of the barometer, and the times of the maximum and minimum readings?**

The diurnal range of the mercury is governed by the daily range of temperature. A rise in temperature reduces the pressure of the atmosphere and a fall in temperature increases the pressure. The times of maximum and minimum readings are influenced by the times of sunrise and sunset, and as the length of the day within the tropics does not vary much in the course of a year, the diurnal range of the barometer is consequently more regular and uniform in tropical regions than in other regions.

CHAPTER IV.

WINDS, THEIR CAUSES AND DISTRIBUTION.

51. How may the force of the wind be estimated by inspection of a weather chart?

The strength of the wind is roughly proportional to the pressure gradient; the steeper the gradient the stronger the wind. The isobars will therefore be widely spaced where the wind is light or moderate, and crowded together where it is strong.

***52. What standard is adopted in the British Isles for estimating the barometrical gradient?**

The difference in pressure, expressed in hundredths of an inch, in 15 sea miles of distance.

***53. What effect has the rotation of the earth on a current of air?**

In the north hemisphere it causes a current of air to be deflected to the right, so that a north wind blows from a north-easterly direction and a south wind from the south-west.

In the south hemisphere it is deflected to the left, so that a south wind blows from a south-easterly direction and a north wind from the north-west.

54. Explain why the wind circulates with a left-handed motion round an area of low pressure in the north hemisphere.

By the earth's rotation the wind from the north, which enters the system on its polar side, is deflected towards the south-west, and the wind from the south which

enters the system on its equatorial side, is deflected to the north-east, the joint influence of which is to set up a left-handed circulation.

See plate xxx., page 70, *Barometer Manual.*

*** 55. What is the origin of the term cyclone?**

Cyclone is derived from the Greek word *Kuklos*, meaning the coil of a snake.

*** 56. Distinguish between a cyclonic system and an anti-cyclonic system.**

In a cyclonic system the wind circulates round an area of low barometric pressure, against watch hands in the north hemisphere, and with watch hands in the south hemisphere. The wind may be light, but it is usually strong and boisterous and may attain to hurricane force in the tropics.

In an anti-cyclonic system the wind circulates round an area of high barometric pressure with watch hands in the north hemisphere and against watch hands in the south hemisphere. The wind is usually moderate and settled weather prevails.

*** 57. State Buys Ballot's Law.**

Face the wind, and the barometer will be lower on your right hand than on your left in the north hemisphere, and lower on your left hand than on your right in the south hemisphere.

*** 58. Does the wind follow the isobars?**

The wind usually blows across the isobars towards the area of low pressure, the angle of inclination being about 20° or 30°, but no definite rule has been established. The angle of obliquity is greater on the outskirts of a depression than near the central area.

59. What information is conveyed by a knowledge of the distribution of atmospheric pressure?

A general idea may be formed of the prevailing winds in different regions.

***60. Where are the principal areas of permanent high barometrical pressure situated?**

In the high pressure belts which lie to the north and south of the equatorial low pressure belt. These more or less circular areas of relatively high pressure are situated on the North and South Atlantic, the Indian Ocean, the continent of Asia, and on the east side of the North and South Pacific. Their shape and extent vary slightly from month to month, but they lie approximately between the parallels of 20° and 40° latitude.

See plates v. to xvii., *Barometer Manual.*

61. Why are the synoptic charts for January and July specially important?

Because the distribution of pressure and wind over the oceans in the month of January is characteristic of the pressure and wind distribution during the period of five months—November to March, and July for the period of five months—May to September.

In the following 8 questions reference should also be made to plates xxviii. and xxix., *Barometer Manual.*

62. What influence have the areas of permanent high pressure on the atmospheric circulation?

These areas form fairly well defined anti-cyclonic systems.

The air circulates round the area of high pressure, right-handed in the north hemisphere and left-handed in the south hemisphere, but the circulation is frequently

interrupted, especially in the western semi-circles of the systems.

63. Describe the main atmospheric circulation over the North Atlantic.

The circulation is clockwise, being controlled by the area of permanent high pressure lying over mid-ocean. North of 40° latitude the prevailing winds are from south-west to north-west. On the east side of the Atlantic the north-east trades prevail. The wind hauls more easterly between the parallels of 10° and 20° north—and the prevailing winds on the east coast of North America are from the southward.

64. Describe the main atmospheric circulation of the South Atlantic Ocean.

The direction of the wind, circulating counter-clockwise about the central area of high pressure is, broadly stated, from south to south-east along the African Coast (the south-east trades), then more easterly on the equatorial side of the anti-cyclonic system, and from the north-west on its western segment. The prevailing winds on the southern segment are from north-west to south-west.

65. Describe the atmospheric circulation over the North Pacific Ocean.

On the east side of the Pacific the wind is from north to north-east (the north-east trades), hauling to a more easterly direction in the equatorial segment of the anti-cyclone. On the western side of the ocean, the wind is somewhat variable, being modified by the periodical alterations of pressure over the continent of Asia which produce the monsoons, but the direction is usually from south-east to south-west.

To the north of the 40th parallel the prevailing winds are from the westward.

66. Describe the atmospheric circulation of the South Pacific Ocean.

The circulation is from south-east (the south-east trades) along the West Coast of South America, and across the northern segment of the anti-cyclone.

On the western segment of the system, the wind is chiefly from the northward, and westerly winds prevail to the southward of 40° latitude.

On the west side of the South Pacific, between the permanent high pressure area and the Australian Coast the prevailing wind is from south to south-east.

67. Describe the atmospheric circulation of the Indian Ocean.

The air circulation is from the westward on the southern segment of the high pressure area, then from the south-east (the south-east trades) on its eastern segment. On the northern segment the wind is more easterly but the direction is subject to a seasonal change due to the influence of the monsoons.

The north-east monsoon prevails from October to March, and the south-west monsoon from April to September.

68. What influence has the sun on the movements of the areas of permanent pressure situated on the great oceans?

During the northern summer the land of the north hemisphere is gaining heat, and the land in the corresponding latitudes of the south hemisphere is losing it, the air over the adjacent seas and oceans undergoing a similar change.

When the sun is moving northward from the equator, the equatorial belt of low pressure surrounding the globe, together with the relatively high pressure belts lying

north and south of it, move slightly northward with the sun.

Conversely, during the southern summer the land in the south hemisphere is gaining heat and the land in the corresponding latitudes of the north hemisphere is losing it. When the sun is travelling from the equator towards its maximum south declination, the equatorial belt of low pressure, together with the high pressure belts north and south of it, move for a short distance to the southward along with the sun.

69. What effect has changes in the average pressure distribution upon the general circulation of the air in the North Pacific and South Pacific?

Bearing in mind that changes in the shape and extent of the permanent areas are associated with the sun's motion in declination, we find that when the sun is north of the equator the region covered by the westerly winds in the North Pacific is greater in extent and the region covered by the north-east trades is less in extent than when the sun had south declination.

The south-west monsoon is induced in the China Sea in place of the north-east monsoon. The area of the south-east trades is contracted on the east side of the South Pacific and augmented on the western side, also that the equatorial belt of variable winds and calms is greatly reduced in width during the northern summer.

CHAPTER V.

WINDS AND GALES OF TEMPERATE ZONES.

70. What winds will a vessel generally experience on a passage from the United Kingdom to the equator?

Vessels when crossing the Bay of Biscay usually experience a westerly wind, which gradually veers to the north and into the north-east trades as she makes southing. As the vessel passes along the east, south-east and southern sides of the high pressure area of the North Atlantic, the wind usually hauls more and more easterly until the equatorial calms are reached.

Plates xxviii. and xxix., *Barometer Manual.*

71. A vessel on a passage in the North Atlantic sailing northward from the equator experiences a change of wind from south-east to south and south-west. What information regarding her track does a synoptic chart convey?

That she has probably passed along the south-west, west and north-west sides of the area of high pressure.

Plates xxviii. and xxix., *Barometer Manual.*

72. What winds would a homeward bound vessel experience after rounding the Cape of Good Hope?

First a south-west wind backing to south and into the south-east trades as she progresses northward along the eastern semi-circle of the high pressure area situated in the South Atlantic.

Plates xxviii. and xxix., *Barometer Manual.*

73. Define the terms "veering" and "backing."

Veering means the wind changing its direction with watch hands, that is, from north round by east to south

and west; and backing means against watch hands, namely, from north round by west to south and east.

74. A vessel is situated in the southern semi-circle of an area of low pressure in the North Atlantic, what changes of wind is she likely to experience?

From south-west to west and then a sudden and heavy shift of wind to N.W. (*See* fig. ii., A., positions *d*, *e*, and *f*.)

75. If situated in the northern semi-circle what change of wind may be expected?

From south-east to east gradually working into a moderate north-east wind. (*See* fig. ii., A., positions *a*, *b* and *c*.)

76. Situated to the south of an area of low pressure in the south hemisphere, what changes of wind will probably be experienced?

The wind may be expected to veer from north-east to east and south-east. (*See* fig. iii., F., positions *a*, *b* and *c*.)

77. If situated in the northern semi-circle of a cyclonic system in the south hemisphere, what are the usual changes of wind?

From north-west to west and then a sudden and heavy shift of wind to south-west. (*See* fig. iii., F., positions *d*, *e* and *f*.)

78. What information is necessary in order to forecast probable changes of wind and weather?

The shape of an area of low pressure, its gradients, the rate at which it is increasing or decreasing in intensity, the direction in which it is moving and its speed.

79. Under what handicap does the seaman suffer when trying to predict changes of weather?

Ignorance of the atmospheric conditions prevailing over adjacent localities. The seaman has to rely absolutely on the weather information conveyed by his own instruments, experience and intelligence, unless his ship is fitted with wireless telegraphy.

80. What does a sudden rise or fall of the barometer indicate?

A rapid change of pressure, indicating an increase or decrease in the force of the wind.

81. In what respects do cyclones of temperate zones differ from the cyclones of the tropics?

They seldom have the central calm peculiar to tropical cyclones, the force of the wind is not usually so great, and the depressions usually spread over a larger area; then cyclonic systems of the temperate zones travel to the eastward while those of tropical regions travel at first to the westward.

82. In a north hemisphere gale, wind from south-west, what changes of weather may the seaman expect?

The south-west wind is invariably accompanied by overcast sky and drizzling rain. The barometer may be expected to rise slightly, the sky to brighten a little towards the north-west, and then a sudden shift of wind to that direction. The temperature falls a bit, and the weather may settle down into a north-west gale. (*See* fig. ii., A, positions *d*, *e* and *f*.)

83. In a south hemisphere gale, wind from north-west, what changes of weather may the seaman expect?

Overcast sky and drizzling rain usually accompany the north-west wind. The barometer may be expected to rise

slightly, and when it does the sky will brighten a little towards the south-west accompanied by a sudden and heavy squall of wind and rain from that direction, The temperature falls a little and the weather generally settles down into a steady south-west gale.

(*See* fig. iii., F., positions *d*, *e*, and *f*.)

84. Does the tack on which a ship is sailing have any influence on the change of her barometer reading? State reasons for your answer.

Yes, when on the starboard tack in the north hemisphere and on the port tack in the south hemisphere, the barometer has a tendency to rise, because the vessel is then heading away from the area of lowest pressure in the respective hemispheres. By Buys Ballot's law the low barometer lies from 8 to 12 points to the right of the direction of the wind in the north hemisphere, and to the left of its direction in the south hemisphere, consequently when on the starboard tack in the north hemisphere and on the port tack in the south hemisphere, the lowest barometer reading will be pretty nearly astern. (*See* Fig. 1.)

85. Is this rule regarding tacks always strictly applicable?

No, only when the position of the ship relatively to the position of the storm undergoes no material change.

86. What complication is introduced when the ship is under way?

The proper sequence of the change of weather due to the progressive motion of the storm alone may be obscured by the speed and the direction at which the ship is approaching or receding from the centre of the disturbance.

(*See* figs. xxi. and xxii. in *Barometer Manual.*)

87. Two barograph traces of cross-Atlantic voyages are placed before you. How could you distinguish the west-bound record from the east-bound record? Give reasons.

By comparing the fluctuations of pressure. The west-bound ship would be meeting the east-going depressions and steaming through them, so her barometer would rise and fall more rapidly and more frequently than the east-bound ship, which would be travelling along with the depressions, and carrying a steadier barometer.

The outward bound ship would also experience more frequent changes in the direction of the wind than the homeward bound.

(*See* fig. xxiv., *Barometer Manual.*)

***88. On what does the force of the wind depend? Is the rate of rise or fall of the barometer in itself an indication of the force of the wind? Give reason.**

The force of the wind depends on the steepness of the barometrical gradient.

The rate of rise or fall of the mercury depends on the rate at which the barometer is crossing the isobars. If a cyclonic system having a steep gradient is stationary, the wind will blow furiously while the barometer keeps steady. Should, however, a system having a slight gradient be moving quickly towards the observer, his barometer will fall quickly although the wind would not be strong.

89. A sailing vessel homeward bound from the southward, making the south coast of Ireland, experiences a strong southerly wind and falling barometer. What should she do?

Prepare for a gale and a shift of wind to the westward. The ship is probably situated in the southern segment of a depression. If not prudent to keep going, heave to on the starboard tack, it is the coming up tack; she will

stem the sea better and head away from the low barometer which is approaching from the westward.

(*See* fig. i., A, position *d*.)

90. Explain why a ship when running down her easting to Australia frequently carries a strong westerly gale for days?

Because the system is also travelling to the eastward and the ship is keeping company with it. She is situated in the northern semi-circle of a south hemisphere depression, in which the wind begins from north-west and backs to west and south-west. (*See* fig. iii., F., positions *d*, *e* and *f*.)

91. A sailing ship bound west off the Cape of Good Hope encounters a fresh northerly breeze and falling barometer. What should she do?

Keep on the starboard tack to make westing. The barometer will probably continue to fall. If the wind freshens into a gale put her on the port tack. This is the coming up tack, the wind will haul more abeam, and the ship will head the sea better. (*See* fig. iii., F., position *d*.)

CHAPTER VI.

TROPICAL REVOLVING STORMS.

92. What object should the seaman try to attain when manœuvring his ship in a tropical cyclone, and why?

He should endeavour to keep clear of the central area which is the region of maximum danger. In the vicinity of the centre the force of the wind is greatest, the changes in its direction are most sudden and sea most dangerous.

***93. Describe the geographical conditions which are most favourable to the formation and development of cyclones. Give examples.**

Large continents having a wide expanse of sea to the eastward in which there are many islands, especially coastlines running north and south.

Gulf of Mexico, East Coasts of Africa and Australia, coast of China.

***94. What progressive speed do revolving storms attain, and over what areas do they extend?**

Their speed varies considerably, not only in different localities, but in the same locality and even in the same storm. Their average rate of progress being in the—

West Indies 300 miles per day.

Arabian Sea, Bay of Bengal, China Sea } 200 miles per day.

Indian Ocean, South Pacific Ocean } 50 to 200 miles per day.

At the beginning and end of the cyclone season in the Indian Ocean they travel at their slowest speed.

The diameter of revolving storms varies from 20 miles to several hundred miles.

***95. Describe the track followed by revolving storms travelling from the tropics into the temperate zones.**

They usually originate a few degrees from the equator and, following a parabolic curve, first proceed in a westerly direction, hauling more and more towards the pole of their respective hemispheres, then in about 25° or 30° latitude they begin to make easting. They expand in dimensions as they proceed, decrease in intensity and dissipate. (*See* figs. ii. and iii.)

***96. What are the two principal points a seaman should know on the approach of a cyclone, and explain clearly how they are determined?**

First, the bearing of the centre from the ship. Second, in which semi-circle the ship is situated.

The first point is found approximately by Buys Ballot's Law, the centre bearing from 12 to 8 points to the right of the direction of the wind in the north hemisphere and to the left of its direction in the south hemisphere.

The second point may be determined by stopping the ship. The progressive motion of the storm will cause the wind to change to the right hand if the ship is on the right hand side of the line of progression and to the left hand if she is on the left hand side. Should the wind remain steady in direction the ship is in the direct path of the storm.

97. Why should more than 8 points from the direction of the wind be allowed when estimating the bearing of the centre?

To allow for the uncertain incurvature of the wind.

The angle of inclination of the wind is greater on the outskirts of the storm field than near the centre, where the wind is considered to make an eddy round a central calm. For this reason the general rule is to allow about 12 points from the direction of the wind when the storm begins, 10 points when the barometer has fallen $\frac{3}{10}$ of an inch and 8 points when it has fallen $\frac{6}{10}$ of an inch or more. The barometer may stand as much as 2 inches lower at the centre than on the outskirts of the storm field.

***98. Which are the dangerous and navigable semi-circles of a tropical cyclone, and give reasons?**

The dangerous semi-circles are the right hand in the north hemisphere and left hand in the south hemisphere, the corresponding left hand and right hand being respectively the navigable semi-circles.

The reason assigned for the names is that a vessel caught in the dangerous semi-circle is in danger of getting further involved in the storm, especially if she is kept before the wind; but if on the navigable side, the ship can get clear of the centre by keeping the wind well aft. (*See* figs. ii. and iii.)

***99. What are the usual indications of an approaching cyclone?**

An unsteady barometer, or a cessation of its diurnal range—ugly threatening appearance of the weather, and a rising wind, with the number and severity of the gusts increasing—a confused sea, superimposed on a long heavy swell which generally comes from the direction in which the storm is approaching.

100. State the rules laid down for the guidance of a seamen in manœuvring his ship in a revolving storm.

North hemisphere.—In right hand semi-circle heave to on starboard tack, or, if in a steamer heave to, keeping

the wind ahead, or on the starboard bow. In left hand semi-circle run with the wind on starboard quarter until the barometer commences to rise, then heave to on the port tack if desired. If caught on the line of progression run with the wind on the starboard quarter.

South hemisphere.—In the left hand semi-circle heave to on port tack, or if in a steamer heave to, keeping the wind ahead, or on the port bow.

In the right hand semi-circle, run with the wind on the port quarter until barometer commences to rise, then heave to on starboard tack if desired.

If caught on the line of progression, run with the wind on port quarter. (*See* figs. ii. and iii.)

***101. Name the seasons when revolving storms of the tropical regions are most frequent.**

Locality.	Month.
West Indies.	July to November.
China Sea.	May to November.
Indian Ocean.	November to May.
South Pacific.	December to March.
Arabian Sea.	May and June also October and November.
Bay of Bengal.	May to November.

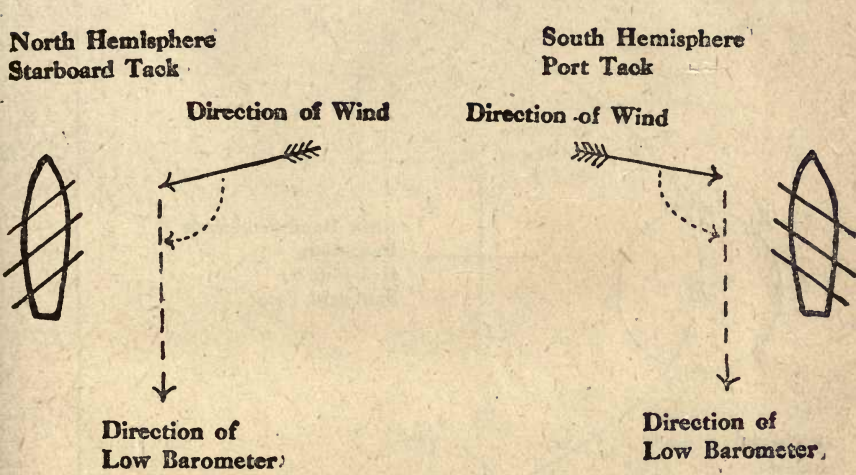

North Hemisphere
Starboard Tack
Direction of Wind
Direction of
Low Barometer
South Hemisphere
Port Tack
Direction of Wind
Direction of
Low Barometer

FIGURE I.

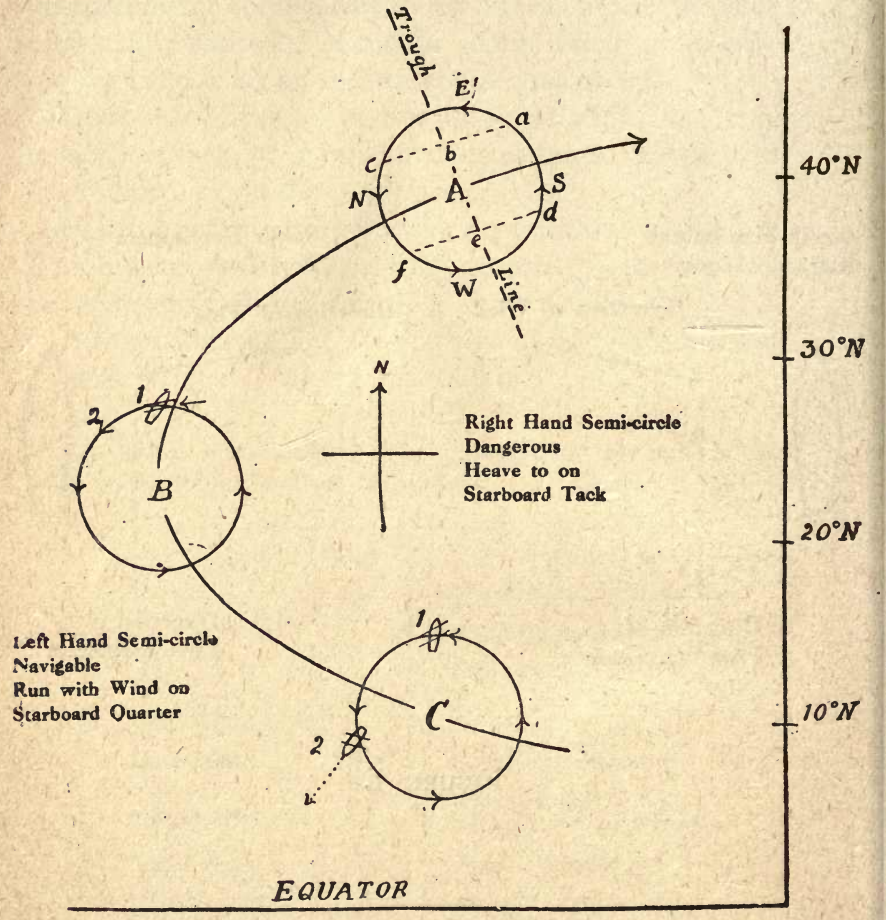


FIGURE II.

A. Positions *a*, *b*, *c*, represent the successive positions of a vessel situated in the northern semi-circle of an advancing depression, and positions *d*, *e*, *f*, if she were situated in the southern semi-circle.

B. Position *1* represents a vessel caught on the line of progression and having no room to run, has been hove to on the starboard tack.

C. Position *1* represents a vessel hove to on the starboard tack.
Position *2* represents a vessel running with the wind on the starboard quarter.

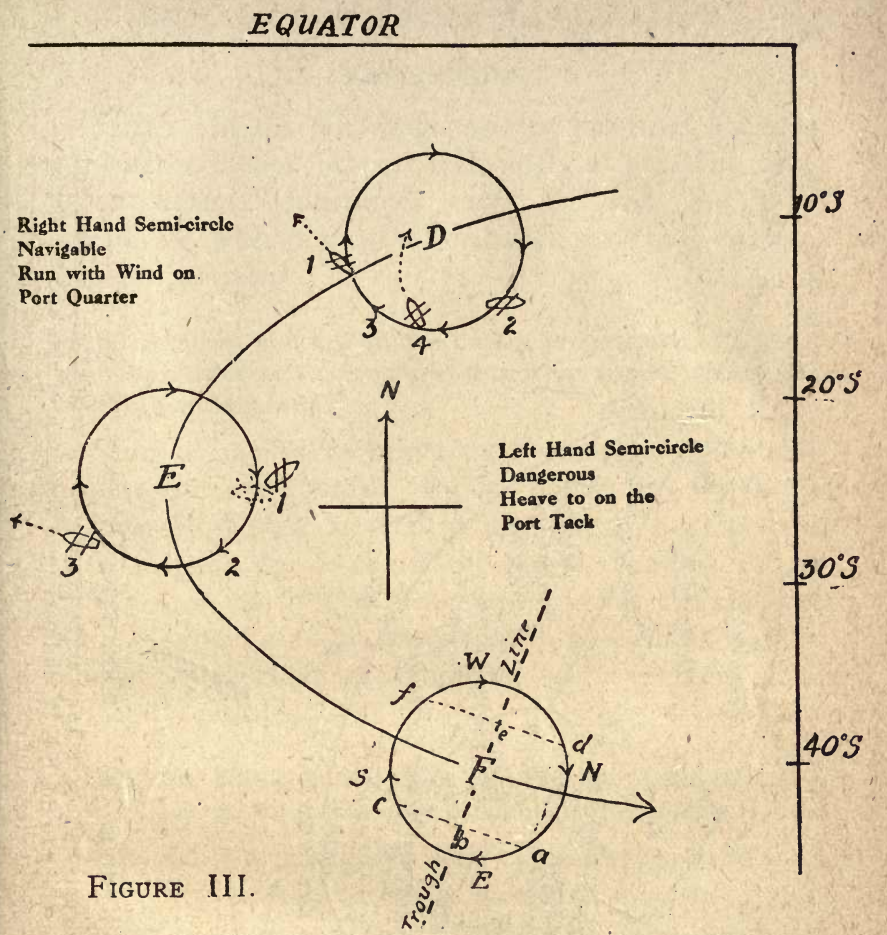


FIGURE III.

D. Position *1* represents a vessel caught on the line of progression and running with the wind on the port quarter. Position *2* represents a vessel hove to on the port tack. Position *3* represents the position of a vessel experiencing a strong and increasing S.E. trade wind which may develop into a cyclone. Position *4* represents the track a vessel would make if the wind were kept continuously on the starboard quarter.

E. Position *1* represents a vessel which had the wind on starboard beam, then wore round to the port tack. Position *2* represents the position of a vessel experiencing a N.E. gale, which may develop into a cyclone. Position *3* represents a vessel running with wind on her port quarter.

F. Positions *a, b, c,* represent the successive positions of a vessel situated in the southern semi-circle of an advancing depression, and *d, e, f,* if she were situated in the northern semi-circle.

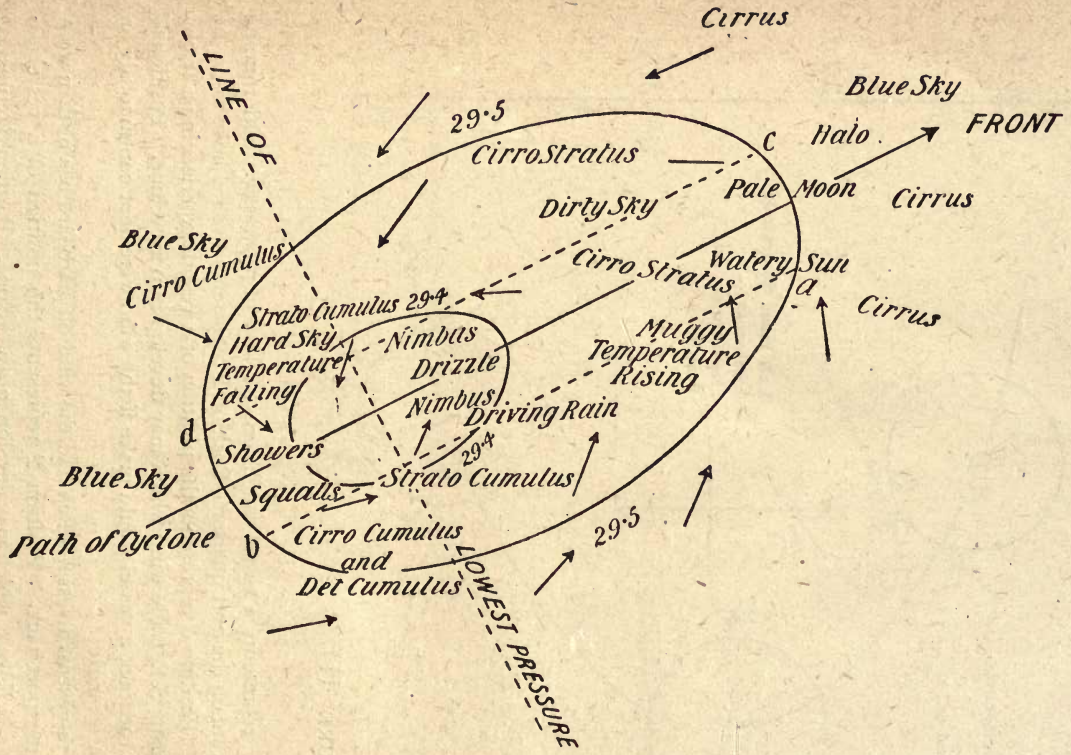


FIGURE IV.—PROGNOSTIC DIAGRAM.

The dotted line *ab* represents the successive positions of an observer relatively to the path and centre of a depression travelling to the E.N.E., and passing to the north of him, and the dotted line *cd* when the centre passes to the south of the observer. The diagram shows the sequence of wind, weather and cloud usually experienced in the British Isles during the passage of a cyclone.

MANŒUVRING.

NOTE:—In the following answers, the rules heave to on starboard tack or port tack apply to a sailing ship; for a steamer, substitute heave to with the wind ahead, or with the wind on starboard bow or port bow respectively.

***102. Suppose you are on the line of progression of a West India hurricane and no room to run, what would you do and explain your reasons?**

Being compelled to heave to, I would keep the ship on the starboard tack. By so doing she would be heading away from the centre, then there is always the possibility of the track of the storm, bending to the eastward of north and the centre passing clear of the ship. I would take all seamanlike precautions to guard against the effects of exceptionally heavy weather. (*See* fig. ii., B., position *1.*)

***103. Your ship is in the track of a cyclone in the southern hemisphere, what is the most prudent course to take?**

Run into the navigable semi-circle, keeping the wind on the port quarter, until the barometer begins to rise, then heave to on starboard tack, or, if more desirable, keep running. (*See* fig. iii., D., position *1.*)

***104. You have reason to believe you are in the right hand semi-circle of a revolving storm in the northern hemisphere, what action would you take?**

Heave to on starboard tack, the ship is in the dangerous semi-circle. (*See* fig. ii., C., position *1.*)

***105. Northern hemisphere, left hand semi-circle, what would you do?**

Run with the wind on the starboard quarter, until the

barometer begins to rise, then heave to on the port tack. (*See* fig. ii., C., position *2.*)

*** 106. You have reason to believe you are in a tropical cyclone, south hemisphere, left hand semi-circle, wind on starboard beam. What alteration of course would you make, if any?**

The ship is heading for the centre, and has the wind on the wrong side. I would wear ship and get her on the port tack, as it is the coming up tack. (*See* fig. iii., E., position *1.*)

*** 107. South hemisphere, strong trade wind, increasing in force, what would you do?**

The south-east trades sometimes freshen into the south-east wind of an advancing cyclone. I would heave to, and study closely the change of wind, the barometer and the weather.

If the barometer falls, and the wind remains steady in direction, or changes to the right hand, I would run to the north-west, but if it changes to the left hand, I would heave to on the port tack. (*See* fig. iii., D., position *1* and *3.*)

*** 108. North-east gale—Indian Ocean—falling barometer, what precautions would you take?**

Heave to, and act as in foregoing answer. (*See* fig. iii., E., position *2.*)

*** 109. Left hand semi-circle, southern hemisphere cyclone, you run with the wind on the starboard quarter, what changes of wind and weather would you experience?**

The changes would depend somewhat on the position of the ship with regard to the centre of the storm and the relative speeds of the ship and storm.

The course of the ship would have to be altered from time to time as the wind changed, in order to keep it at the same angle on the starboard quarter; the ship would therefore be sailing along a spiral track and approaching the centre.

The barometer would fall, the wind would increase in force and change in direction at shorter intervals, squalls more frequent and violent, and the sea more confused and dangerous.

Should the ship run into the centre a calm of short duration may be experienced, then the wind would come with renewed violence from an opposite direction. (*See* fig. iii., D., position *4*.)

TRACKS.

See PLATE xxxiii., *Barometer Manual.*

***110. Describe the hurricanes of the North Atlantic, their track and season?**

They originate to the eastward in about 10° north latitude and travel in a west-north-west direction towards the West Indies, hauling more northerly as they proceed. Some sweep over the Gulf of Mexico, but the majority recurve to the eastward of north in about latitude 30°.

Season—July to November.

*** 111. Describe the cyclones of the Indian Ocean, their track and season.**

They originate about latitude 10° S., longitude 70° E., and travel in a west-south-west direction towards Mauritius, hauling more southerly as they proceed, and recurve to the eastward of south in about 20° latitude. Their point of curvature, sometimes called the cod of the storm, varies considerably in both latitude and longitude.

Season—November to May.

*** 112. Describe the cyclones of the South Pacific, their track and season.**

They generally originate to the north-east of the Fiji Islands, and travel to the south-west, hauling more poleward as they proceed, recurving to the south-east in about 20° latitude.

Season—December to March.

*** 113. Describe the typhoons of the China Seas, their track and season.**

They originate usually in the North Pacific to the eastward of the Philippines, and travel in a west-north-westerly direction towards the China coast. Some recurve to the north, sweep over Japan, and then expend themselves when travelling in a north-east direction.

Season—May to November.

*** 114. Describe the track of cyclones in the Bay of Bengal and Arabian Sea, and give the seasons when they are most frequent.**

Bay of Bengal:—They may originate anywhere in the Bay, and travel either north-west towards the Madras coast, or north and north-easterly towards the head of the Bay.

Season—May to November.

Arabian Sea:—They may originate near the Laccadive Islands, or on the Indian coast, and travel in a north-westerly direction towards the Arabian coast.

They most frequently occur during the change of the monsoons, namely May and June and again during October and November.

Additional cyclone questions are given in the Addenda, page 73.

PART II.

"The Seaman's Handbook on Meteorology."

CHAPTER I.

THE ATMOSPHERE AND ITS CIRCULATION.

*** 115. Describe the atmosphere, its composition, height and density.**

The atmosphere is a gaseous envelope, surrounding our globe, and is composed approximately of—

Nitrogen	77	per cent.
Oxygen	21	,,
Aqueous vapour	1	,,
Argon, etc.,	1	,,

Its actual height is not known, but by observing the different points where meteors become luminous, it is estimated to be at least 100 miles high, and in a more rarified form may extend much higher.

It is densest at the earth's surface, the density diminishing as the height increases. 7 miles high the density is $\frac{1}{4}$ the surface density. 14 miles high the density is $\frac{1}{16}$ the surface density.

*** 116. What effect has temperature on the capacity of the atmosphere to absorb moisture?**

The higher its temperature the greater is the capacity of the atmosphere to hold moisture in suspension. Hence the reason why there is more moisture in the air

during summer than in winter, and also why the atmosphere is more humid and oppressive in tropical regions than elsewhere.

***117. What are the principal causes of wind?**

Wind is caused by differences in the pressure of the atmosphere, the air moving from the regions of relatively high to the regions of relatively low barometrical pressure, in an endeavour to restore the atmospheric equilibrium.

These changes of pressure are produced mainly by differences in temperature brought about by the unequal distribution of land and sea, by clouds, rain and geographical position.

***118. What is the effect of difference of temperature in adjacent localities on the equilibrium of the atmosphere?**

When the air is heated it expands, becomes lighter and rises into the higher regions of the atmosphere.

The colder and relatively heavier air flows inward from the adjacent localities to supply the place of the ascending column of air, and thus restores the equilibrium of the atmosphere.

CHAPTER II.

TEMPERATURE AND HUMIDITY.

119. Define what is meant by temperature.

Temperature is the thermal condition of a body which determines the interchange of heat between it and other bodies.

120. How may heat be transmitted? Give examples.

By conduction, by convexion, and by radiation.

Conduction is the process of heat passing from one particle of a body to the next particle, and so conveying the heat from the hotter to the colder parts.

Example:—The lower strata of air may be heated by contact with the earth's surface and the heat thus acquired is passed from one particle of air to the next particle.

Convexion is the process of conveying heat when the heated particles actually move from one part to another, thus distributing their heat.

Example:—Particles of air when heated rise and flow to other localities, thus conveying and distributing their heat by convexion.

Radiation is the passing of heat in straight lines from one point to another without unduly heating the medium through which it passes.

Example:—The sun's rays heat the earth through the medium of the atmosphere, but to a greater degree than the air itself.

The temperature of the layers of air close to the earth's surface is raised or lowered by radiation from the earth's surface.

***121. Under what circumstances are the sun's rays hottest, and state your reason?**

The sun's rays have their greatest effect when they fall perpendicularly on the earth's surface, because the rays then pass directly through the layers of atmosphere.

122. Why are the polar regions colder than the temperate zones, and the temperate zones colder than tropical regions?

The heating effect of the sun's rays diminishes as their obliquity increases. The rays fall perpendicularly on the earth's surface in the tropics, hence the greater heat of that region, and the sun's rays fall more and more obliquely as the latitude increases, hence the extreme cold of the polar regions.

***123. Describe terrestrial radiation and its effect on the temperature of the earth's surface?**

Terrestrial radiation is caused by the earth passing its heat into the atmosphere.

Terrestrial radiation lowers the temperature of the earth's surface. Sandy soil loses its heat quicker than loose earth, and loose earth parts with its heat more freely than closely packed soil.

***124. How is terrestrial radiation accelerated and how retarded?**

Accelerated by calm weather and clear sky, retarded by wind and cloudy sky.

***125. Why is the climate more equable and milder on the seaboard than inland?**

Because the sea and the atmosphere lying over it

maintain a more uniform temperature than the land. The land is readily heated or cooled, and the air over the land quickly responds to these changes of temperature. The sea retains its heat and carries the heat by convexion to whither it goes, so that seaboard places enjoy the modifying influences of the sea air, which, as a rule, is relatively warmer or cooler than the air over the land.

126. Why does the temperature of the air decrease as the altitude increases?

Because the heat acquired by contact with the earth and passed from one particle of air to the next particle (conduction) gets less and less as the distance from the earth increases. The pressure of the atmosphere also gets less as the height increases, thus allowing the air to expand, and in the process of expansion the heat is temporarily lost, it becomes latent.

*** 127. What is the range of temperature in the British Isles? Give the maximum and minimum temperatures, also the highest and lowest mean daily temperatures and when they occur.**

The range is about 70°, varying from 10° Fahr. to 80° Fahr.; highest mean daily temperature, 64° Fahr.—15th July; lowest mean daily temperature, 37° Fahr.—12th January.

*** 128. What is an isotherm?**

A line drawn on a chart through places having the same temperature. (Iso is a prefix from a Greek word meaning equal.)

129. When do the maximum and minimum diurnal temperatures occur in the United Kingdom?

The maximum occurs about 2 p.m. The minimum occurs a few minutes after sunrise during the summer and about an hour before sunrise during the winter.

***130. What is aqueous vapour, how is it caused, and what form does it take when leaving the water?**

It is minute particles of water, floating in the atmosphere between the molecules of nitrogen and oxygen and is caused by evaporation.

Aqueous vapour takes the form of invisible vapour when rising from the water, invisible owing to the transparency of the particles of water.

***131. Define the terms vaporisation and evaporation.**

Vaporisation indicates the process of turning a liquid into a gaseous state.

Evaporation refers to the vapour generated at the surface of a liquid or moist surface.

132. What is the difference between dry air and aqueous vapour?

Dry air is constant in quantity and action, but aqueous vapour is constantly changing in quantity and in its form, being converted into water and back again into invisible vapour with changes of temperature.

***133. How are cloud, fog, mist and rain formed?**

When the air is heated it expands and its capacity to hold moisture in an invisible state is increased. When the air is cooled it contracts and the invisible moisture held in suspension is formed into particles of water and becomes visible in the form of cloud, fog or mist.

If the temperature of the air be further reduced, greater contraction takes place, the air becomes charged below the point of saturation, and the excess of moisture is precipitated in the form of rain.

***134. What happens to the heat used in changing water into vapour?**

It becomes latent. The heat is absorbed or hidden

for the time being—at least it cannot be detected with a thermometer—but it reappears when the vapour is restored to its liquid state.

Note.—A conception of latent heat may be conveyed by means of the following experiment:—Place a block of ice in a pan, apply heat and put a thermometer on the ice. During the time it is melting, the ice will be found to remain at the same temperature, 32° Fahr. The heat imparted from the fire to the ice is apparently used up in converting it into water, it is not perceptible, it is said to be latent.

When the ice is dissolved every addition of heat increases the temperature of the water until it reaches boiling point, 212° Fahr. Continue applying the heat, and the boiling water is slowly converted into vapour, but the thermometer in the boiling water registers the same temperature during the process of conversion. The heat used in converting the water into vapour is hidden, it has become latent.

135. What processes may cause the air to be cooled?

The intermingling with air currents of a lower temperature, radiation, contact with cold surfaces, or loss of heat when rising to higher altitudes.

***136. Explain the terms relative humidity and dew point.**

Relative humidity is the percentage of moisture to saturation, dry air being represented as 0, and saturation as 100. Thus, when the air is found to contain one half as much water vapour as would be necessary to saturate it, the relative humidity would be expressed as 50 per cent.

Dew point is the temperature below which the air must be cooled in order to cause condensation of vapour.

CHAPTER III.

ATMOSPHERIC PRESSURE AND WIND.

*** 137. Does the wind follow the isobars?**

Only approximately so. The wind blows obliquely across the isobars towards the area of low pressure at an uncertain angle which varies up to about 30 degrees.

*** 138. What is a pressure gradient?**

The distribution of pressure over a given area as indicated by the isobaric lines on a synoptic chart.

139. How is a gradient calculated?

Formula :—

$$\text{Gradient} = \frac{\text{difference of barometer readings} \times 15 \text{ miles}}{\text{perpendicular distance between the isobars.}}$$

140. The perpendicular distance between the isobars, 30·2 inches and 29·7 inches, is 120 miles, what is the gradient?

$$\text{Gradient} = \frac{\cdot 5 \text{ inches} \times 15 \text{ miles}}{120 \text{ miles}} = \cdot 062 \text{ inches per } 15 \text{ miles.}$$

*** 141. Is the actual wind velocity greater or less than the theoretical velocity as deduced from the gradient? State your reasons.**

The theoretical velocity is about one-third greater than the actual velocity of the wind. The retardation of the wind due to friction with the earth's surface and also the effect of the variable angle at which the wind crosses the isobars are not taken into account in the formula.

CHAPTER IV.

CLOUDS.

***142. What are clouds composed of, and describe how they are formed?**

A cloud is composed of minute particles of water. If formed when the temperature is below freezing point a cloud may consist of frozen vapour particles. Cloud is formed by the aqueous vapour being cooled below the point of saturation, either by a rising current of air reaching the colder regions of the atmosphere, or by mixing with air currents of a lower temperature.

143. Why do clouds frequently disperse at night?

Clouds are held in suspension chiefly by the heated air rising from the earth's surface. These up-flowing currents are brisker during the day, owing to the air being warmer than at night. After sunset the earth's surface is cooled, the ascending currents of air also lose heat, their upward flow is arrested, and the cloud dissolves.

***144. Name the standard types of clouds as classified by the International Committee, and give the abbreviations.**

Cirrus - - -	(Ci.)	Cumulus - - -	(Cu.)
Stratus - - -	(St.)	Nimbus - - -	(Nb.)
Cirro-cumulus	(Ci-cu.)	Cirro-Stratus	(Ci-st.)
Alto-cumulus	(A-cu.)	Alto-stratus	(A-st.)
Strato-cumulus	(St-cu.)	Cumulo-nimbus	(Cu-nb.)

***145. Describe cirrus clouds.**

They are composed of frozen vapour particles, and arrange themselves in white feather-like tufts and threads (mare's tails). Cirrus is the highest form of cloud, from 5 to 7 miles high. It is a sign of wind.

*** 146. Describe cumulus.**

The woolpack.—Heavy masses of solid looking white cloud, resembling the volume of steam ejected from a railway engine when starting. They often appear brilliantly white, depending on how the light falls on them, with well defined shadows which give them a rounded appearance.

*** 147. Describe stratus.**

The lowest form of cloud, sometimes resting on hill tops. They resemble mist and often appear in parallel layers, hence the name stratus.

*** 148. Describe nimbus.**

The rain cloud.—Heavy dark shapeless clouds bringing rain or snow.

***149. Describe cirro-cumulus.**

The mackerel sky.—Small, well defined globular clouds, high in the sky, which frequently arrange themselves in groups and lines and have a dappled appearance. Sign of wind.

***150. Describe cirro-stratus.**

Appears first as horizontal patches of hazy cloud, high in the heavens, which gradually overspreads the sky as a thin haze and through which the sun and moon appear

dimly. It is in this cloud that halos, coronae, and mock suns are formed. Cirro-stratus is a sign of bad weather.

151. Describe strato-cumulus.

Rolls of dark clouds frequently covering the whole sky, especially in winter, and arranged in parallel lines pressed close up to one another. Blue sky may be seen through the spacings. They are seen in cylonic systems but are not usually associated with rain.

152. Describe cumulo-nimbus.

The thunder cloud.—A mass of cumulus with rain in it. It frequently rises from the horizon, arches up, and ends in a squall of wind, rain, or snow.

153. Give the average heights of the different clouds.

Cirrus - - - -	5 to 7	miles	high.
Cirro-stratus - - -	4 to 5	,,	,,
Cirro-cumulus - - -	4 to 5	,,	,,
Strato-cumulus - -	1 to 2	,,	,,
Cumulus - - -	1 to 1½	,,	,,

154. What average speed do clouds travel at?

In summer the average speed of the lowest clouds is about 20 miles per hour, and of the highest 70 miles per hour.

During winter their average speed is 15 to 40 per cent. faster than in summer.

155. The direction of upper clouds is frequently different from that of the lower clouds, and also from the direction of the wind at the earth's surface. How do you account for this?

In an anti-cyclonic system the current of air descends,

and on approaching the earth's surface the air spreads out and flows into the adjacent cyclonic systems.

The central area of a cyclonic system, on the other hand, is composed of a rising and gyrating current of air, which spreads outwards on reaching the upper regions of the atmosphere and is supposed to flow into the top of the adjacent anti-cyclonic systems, the clouds, of course, being carried in the same direction as this overflowing current of air.

It may also happen that the higher clouds are above the influence of the system which is producing the wind at the earth's surface.

156. Describe the sequence of wind, cloud, and weather, experienced by an observer situated in the path of an advancing cyclone in the British Isles.

First the cirrus clouds appear to the south-west, the wind freshens from a south-easterly direction, and the barometer falls. The cirro-stratus haze spreads over the sky, causing a pale moon and watery sun, followed by nimbus and drizzling rain. Meanwhile the barometer continues to fall, the wind changes quickly to the south and south-west. When the trough line is reached there are a few sharp squalls, and the wind flies to the north-west, accompanied by showers and detached cumulus. (*See* fig. iv.)

***157. Describe the weather sequence experienced to the south of the path of a cyclone in the British Isles.**

Cirrus and cirro-cumulus clouds first appear to the westward and the wind freshens from the south-east, with a falling barometer, then cirro-stratus and gloomy sky come along, the wind meanwhile veering gradually to south and south-west. The dirty sky gradually turns into nimbus, drizzling rain, and strato-cumulus.

When the barometer ceases to fall and begins to rise, there will be a few squalls, the wind will come out of the north-west with falling temperature, the sky clears, and patches of blue appear between the detached cumulus. (*See* fig iv., positions on line *a b*.)

158. Describe the sequence of weather experienced on the north side of a depression.

First the cirrus clouds appear, then cirro-stratus with halo and gloomy weather, turning into nimbus and rain, then after the trough has passed, strato-cumulus, cirro-cumulus, and blue sky. The wind beginning from the eastward would back to the north-east and north. (*See* fig. iv., positions on line *c d*.)

CHAPTER V.

MIST—FOG—PRECIPITATION.

*** 159. Describe mist and fog, and what is the difference between fog and mist?**

Fog and mist are cloud at the earth's surface, fog being mist of greater intensity, Both are composed of visible water vapour. The important difference between them from a seaman's point of view is, fog impedes navigation; mist does not.

160. When does fog usually occur?

When winds are light, barometer high, temperature low, and anti-cyclonic conditions prevail.

*** 161. How is sea fog created?**

Usually by a warm wind passing over relatively colder water, the moisture of the air being condensed into visible vapour.

Sometimes a cold wind passing over water having a higher temperature chills the relatively warmer vapour rising from the surface of the sea, and forms fog.

Sea fog may also be caused by the interlacing of hot and cold ocean currents.

162. How may fog be frequently caused on the coast?

By a supply of cold air flowing into a locality after a spell of warm weather, or, conversely, by a replacement of a cold current of air by a warm one after a spell of cold weather.

163. What is the relation of thick weather to wind direction on the home coasts?

In the North Sea fog is most frequent with light southerly winds—south-east to south-west.

In the Straits of Dover, with wind from any direction, especially during October and November.

In English and Bristol Channels, with wind from south to south-west.

In St. George's and Irish Channels, with south-easterly winds.

***164. How is fog intensity recorded in the log book?**

By numbers 0 to 5.

0 meaning a clear horizon.

*f*1 mist—navigation not impeded.

*f*2 and *f*3 moderate fog—signals sounded—lights visible about a mile.

*f*4 and *f*5 thick fog—navigation suspended.

***165. How is rain caused?**

By a decrease in the temperature of the air below the point of saturation.

166. How may the air be cooled, and what is the change of temperature due to height?

The air may be cooled by mixing with colder currents of air, or by rising into the higher regions of the atmosphere. Wet air loses about 1° of temperature for every 300 feet of height.

167. Why is the rainfall usually greater in mountainous districts than elsewhere?

Because the air current on striking the mountain side is deflected upwards. The temperature of the air is

reduced as it rises, and frequently falls below the point of saturation, thus causing an increased rainfall.

*** 168. Why is there more rain on the polar side of a cyclone than on the equatorial side?**

Because winds that enter a cyclonic system on its polar side are relatively colder than the air they displace, and so condensation of the moisture in the warmer air is caused.

169. When is hail most frequent in Europe?

During the late spring and summer months and most common between 11 a.m. and 5 p.m.

170. How is the fall of snow measured?

By thawing out what is caught in the rain gauge; one foot of snow is equal to one inch of rain.

*** 171. Distinguish between halos and coronae. What value are they in forecasting weather?**

A halo is formed of coloured circles, red next the sun or moon, then orange, then yellow.

A corona is a ring or a number of rings round the moon and are usually faint blue. They are frequently seen near the time of full moon.

Halos and coronae are caused by the refraction of light in the frozen vapour particles which form the cirrus clouds.

If the diameter of the corona contracts, sign of rain; if it expands, sign of fair weather.

CHAPTER VI.

ATMOSPHERIC PRESSURE DISTRIBUTION AND WEATHER CONDITIONS.

172. Describe briefly the method adopted at the Meteorological Office in preparing a weather chart.

Whenever the reports come in from the various stations the following information is plotted on the chart :—

(*a*) The direction and force of the wind.
(*b*) Barometer reading (corrected).
(*c*) Readings of wet and dry bulb thermometers.
(*d*) State of the weather in Beaufort notation.

173. Write out in full the Beaufort notation.

b Blue sky.
c Clouds (detached).
d Drizzling rain.
e Wet without rain.
f Foggy.
g Gloomy.
h Hail.
l Lightning.
m Misty.
o Overcast.
p Passing showers.
q Squally.
r Rain.
s Snow.
t Thunder.
u Ugly (threatening appearance of weather).
v Visibility. Objects at a distance unusually visible.
w Dew.
z Haze.

174. What is a synoptic chart?

A chart showing for a given time or period the weather conditions prevailing over a wide area.

175. How could you tell on looking at a weather chart whether the wind in certain localities was strong, moderate, or light?

By the isobars. If they are close together the gradient is steep and the wind strong; if the isobars are widely separated the gradient is slight and the wind moderate or light.

176. What is the baric minimum?

The isobar of lowest barometer reading.

177. What is meant by the trough of a depression?

A line dividing the system between that part in which the barometer is falling and that part in which it is rising. It is usually a line passing near the centre at right angles to the path of the storm.

178. Write out the names of the fundamental forms of isobars.

The cyclone, anti-cyclone, the wedge, the secondary, the "V" shaped depression, and the col.

***179. Describe the weather characteristics of the cyclone.**

In front of the trough the barometer falls, but the temperature rises under the influence of the warm feeding wind from the southward, and the rain begins to fall. In the rear of the trough the barometer rises, but the temperature falls a little under the influence of the northerly winds, the wind is squally and the rain intermittent. (*See* fig. iv.)

180. Describe the wedge formation and the type of weather which accompanies it.

It is an area of relatively high pressure wedged in

between two cyclonic systems. The weather is usually bright, high visibility, wind moderate, and sky clear.

*** 181. Describe the anti-cyclone.**

Light or moderate winds prevail having a clockwise circulation round an area of high barometrical pressure, weather fine, rain and mist in some localities.

*** 182. What is a secondary system?**

A subsidiary depression within a cyclonic system. They are usually located to the south or rear of the primary. The wind in a secondary is generally moderate and light, with rain or snow. A secondary sometimes develops in dimensions and intensity, and it then competes with its primary in importance.

*** 183. Describe the "V" shaped depression.**

It is a particular type of secondary, and derives its name from the shape of the isobars. They develop usually on the southern segment of a cyclonic system and as a rule move eastward with their primary. The weather is unsettled, the sky overcast and cloudy, with squalls and showers.

184. Describe the col.

A lane of relatively low pressure between two anti-cyclones. The winds are generally light and variable, thunderstorms are frequent, and mist or fog are prevalent on the coast during the warmer months of the year.

*** 185. What is a gust, what is a squall, and what produces them?**

A gust is a sudden and transient increase in the force of the wind. A squall is a gust of greater intensity and

longer duration. Both are caused by the meeting and mixing of air currents of different temperatures.

186. What is a waterspout, and how is it caused?

Caused by two air currents of different temperatures colliding in the higher regions of the atmosphere, the air being deflected upwards and downwards. The visible vapour descends to the surface of the sea in a narrow column of whirling air current.

187. Why are squalls frequent near the the trough and in the rear of a cyclonic depression?

Because the warm equatorial wind comes in contact with the colder wind from higher latitudes in the vicinity of the trough, and in the rear of it. The differences in temperature thus produced cause changes in the pressure of the atmosphere, thus forming local gradients conducive to the creation of squalls.

***188. What is a line squall?**

A violent squall caused by a sudden wave of relatively high pressure invading a "V" shaped depression.

A "V" depression, as its name implies, is an elongated and narrow system, which travels broadside on. The trough extends over a long strip of country, and hence the squalls extending along this line have been named line squalls.

CHAPTER VII.

ANTICIPATION OF WEATHER BY OBSERVATION AT A SINGLE STATION.

***189. What are the first indications of an approaching storm before the barometer begins to fall?**

Cirrus clouds are seen working up from the south-west, wind easterly and unsteady, and moisture in the air indicated by the hygrometer.

190. A fresh E.S.E. wind, barometer falling, how does the centre of the depression bear from the observer?

About ten points to the right of the wind—south-west. (*See* fig. ii., A, position *a*.)

191. How may an observer ascertain whether the central area of a depression is passing to the north or south?

If the wind veers, it will pass to the north, because he is then in the right hand semi-circle; if it backs he is in the left hand or northern semi-circle and the centre will pass to the south of his position. (*See* fig. ii., A.)

192. On what does the sequence of weather depend?

On the position of the observer relatively to the path followed by the centre of the depression.

193. Why is the wind often stronger after the baric minimum has passed?

Because an area of low pressure is sometimes closely followed by an area of high pressure, which presses up

behind it, a steeper gradient causing stronger winds is thus formed in the rear of the cyclonic system.

194. Define the term "gale."

Force 8 or upwards of the Beaufort Scale; a velocity of about 40 miles per hour.

195. What are the characteristic features of the weather in an anti-cyclone.

Dryness of the air, weather quiet and warm, misty in the morning, and fog on the coasts, especially in the region of the highest barometer.

196. In forecasting weather, what unforeseen circumstances may vitiate the observer's prediction?

The progressive speed of the depression may be accelerated, retarded or arrested, the gradients may diminish and the system lose its energy, or the normal sequence of the weather may be interfered with by an advancing secondary.

197. During the passage of a cyclonic system over the British Isles, the temperature rises during winter but generally falls during summer. What explanation is given of this?

During winter the sun's rays penetrate the atmosphere with great obliquity and have comparatively little effect in raising the temperature of the air, so that the relatively warm wind from equatorial regions introduces a rise of temperature in front of the trough. During summer the sun's rays approach the perpendicular, and are then most effective in heating up the surrounding atmosphere, but the overcast cloudy sky which accompanies a cyclone

obstructs the sunshine and frequently produces a temporary fall of temperature during its passage.

198. Does the prevailing wind and weather depend on the height of the mercury?

Not always. The force of the wind depends on the gradient. An exceptionally high or low barometer indicates unsettled weather. Should the mercury rise or fall suddenly, the wind invariably increases but if its movements are slow, settled weather usually prevails.

***199. How is dew formed, and what conditions of the atmosphere are most favourable to its formation?**

Dew is deposited when the temperature of the relatively warmer air rising from the earth's surface falls sufficiently to cause condensation of the vapour. Dew is most abundant in calm weather with a clear sky; its formation never begins under an overcast sky or when there is much wind. Dew is an indication of fine weather.

200. What are the usual indications of coming rain?

Clearness of the atmosphere, high visibility, distant objects clearly defined, sounds carrying a long distance, the reflection of objects in the water during the day and of lights at night.

201. The regularity of the average curve of annual temperature in the British Isles is subject to periodical interruptions, especially during April and May—March and November and the earlier half of December and February. To what are these interruptions attributed?

The cold periods of April and May are connected with the annual failure of the Gulf Stream extension to reach

our shores in the spring, combined with an increase in the volume and activity of the Greenland current during these months, and furthermore the air supply of our islands is drawn from the polar regions during this period.

The cold periods of March and November are attributed to an area of high barometrical pressure being created in the neighbourhood of Iceland, thus generating an easterly current of air in the British Isles. It is colder on the Continent during early spring than it is in our country, hence the east wind coming from the relatively colder regions arrests the seasonal rise of temperature in Britain during March.

In November the curve of temperature is falling in this country, but on the Continent no decided fall of temperature has taken place at this season, consequently the relatively warmer east winds of this month may be expected to interrupt the regular fall of temperature.

The mild weather of early December is probably due to the prevalence of southerly winds, and the cold period of February to the deficiency of heat from the sun; in fact, all the periodic interruptions in the seasonal march of temperature may be due to variations in solar heat.

CHAPTER VIII.

TYPES OF WEATHER CONDITIONS.

Note.—Plates xxviii. and xxix. of the *Barometer Manual* illustrate the flow of the chief atmospheric currents, from which it will be noted that a steady stream of air is flowing continuously eastward across the North Atlantic between the parallels of 40° and 60° north.

The whirls of wind which are named cyclones and anti-cyclones may be generated anywhere in the main currents of the atmosphere, and, while maintaining their concentric motion, these eddies of wind are carried along in the main streams in much the same way as whirlpools and eddies are carried along in a fast running stream of water.

The North Atlantic current of air brings with it in rapid succession a continuous stream of these atmospheric whirls, which, when passing over the British Isles, usually travel in an east-north-easterly direction. When a depression passes over a locality at normal speed, an observer experiences a fairly regular sequence of weather changes, from halo to gloom, muggy weather, drizzling rain, driving rain, clearing squalls, showers and then patches of blue sky.

But occasionally a depression is held up for a considerable time, or deflected to one side, by a stubborn system lying in its path and which refuses to be dislodged. When this occurs, the change of weather incidental to the moving system is also arrested and the same weather conditions may prevail in a locality for days or even weeks at a time.

When a depression is divided into several segments, it is found that the wind and the weather experienced in a particular locality depends to a great extent on what segment of the whirl it is situated in, and, as the weather prevailing in corresponding segments of successive cyclones is usually somewhat similar in character, an attempt has been made to classify the weather of these segments into distinctive types, each type being named according to the trend of the isobars, which approximates closely to the direction of the wind.

This chapter in the *Seaman's Handbook* deals with the different types of weather experienced in the British Isles when under the influence of a slow moving system, also with the relative position of contiguous areas of high and low pressure which influence the formation of gradients congenial to the production of particular types of weather.

202. Describe the south-westerly type of weather.

It is established when a low pressure area lies to the north of the British Isles, and a high pressure area over the Bay of Biscay and France.

The wind increases in force, barometer falls, temperature rises, drizzling rain sets in, then heavier rain. The wind then veers and gets squally, barometer rises, temperature falls, passing showers, the sky clears and wind moderates.

Plate xv., figs. i. and iii., *Seaman's Handbook.*

203. Describe the southerly type of weather.

The wind usually backs and freshens, but the weather sequence is similar to the south-westerly type.

The condition most favourable is when a low pressure area exists to the west of the British Isles and a high pressure area over Norway.

Plate xv., fig. ii., *Seaman's Handbook.*

204. Describe the westerly type of weather.

When this type obtains, low barometrical pressure exists over Norway and high pressure over the Bay of Biscay and France.

The wind increases from a westerly direction, backs to the south-west, and afterwards veers to the north-west with a decided fall in temperature.

Plate xv., fig. iv., *Seaman's Handbook.*

205. Describe the northerly and north-easterly types.

When an anti-cyclone lies immediately in the rear of a cyclone, the joint influence of the northerly winds which prevail on the east side of the anti-cyclone and on the west side of the cyclone produces this type of weather in a locality situated between the high and low pressure systems.

The northerly type is generally experienced in May and the north-easterly in March. The polar wind produces a decided fall in temperature.

Plate xvi., figs. ii. and iii., *Seaman's Handbook.*

206. Describe the easterly type of weather.

Due to a stationary anti-cyclone lying to the north of the British Isles, and a low pressure system pressing against its southern segment, thus producing a steeper gradient for east wind. It may prevail for weeks. The wind fluctuates between south-east and east, with rain and rising barometer. When the wind backs temporarily to the north-east the weather is fairer but colder.

Plate xvi., fig. v., *Seaman's Handbook.*

CHAPTER IX.

GALES ON THE COASTS OF THE BRITISH ISLES.

207. Define what is meant by a gale.

Wind of force 8 and upwards of the Beaufort Scale, equivalent to a velocity of about 40 miles per hour.

208. What is the average annual frequency of gales in the British Isles?

An average of about 48 gales per year.

209. During what months are gales most prevalent?

October to March, the greatest number in January, fewest in June and July.

210. Classify the gales of the United Kingdom in the order of their frequency and according to the quadrant of the compass from which they blow.

Gales from the south-west are most frequent, then those from the north-west, then south-east, and lastly the north-east gales, which are the least frequent of all.

211. What is meant by a vortical gale?

A gale whose centre passes over the central parts of the United Kingdom, thereby enabling the wind to make a complete circuit over the British Isles.

212. State the relative frequency of gales from various points of the compass, and the seasons when they are most prevalent.

Gales from south-west to north-west predominate all the year round. Gales from north-east to south-east are

most frequent during spring and autumn; a few are experienced in winter, but they seldom occur in summer.

Easterly gales are the most prevalent on the East Coast of the United Kingdom; south-west gales on the South Coast of England, and gales anywhere from south to north-west over Ireland and Scotland.

213. What is the average speed of travel of gales in the United Kingdom?

From 10 to 50 miles per hour, the average speed being about 25 miles per hour. The average speed is greatest during winter and least during autumn.

CHAPTER X.

ICEBERGS AND OTHER FORMS OF DRIFTING ICE.

214. What is ice and how is it formed?

Ice is composed of crystals formed in a freezing fluid when being converted from a liquid to a solid state. It is also formed from snow which has been subjected to such a pressure that all air has been expelled from the particles of snow.

215. What is meant by regelation?

The property possessed by lumps of ice to separate from each other when subjected to pressure, and to freeze together again when the pressure is removed.

*** 216. What is a glacier, and how are glaciers formed?**

A slow moving river of ice. It is formed on the slopes of lofty mountains from snow compacted into ice by pressure.

***217. Describe the "calving" of an iceberg.**

The glaciers of the polar regions are pressed down the valleys towards the coast by the accumulative pressure of the frozen snow in the rear.

On reaching the coast the front part of the glacier is pushed forward, it protrudes to seaward until it is water borne. The effect of the unequal strain caused by its own weight, and also of the action of the sea, causes a portion of the glacier to break off and to float away as an iceberg.

218. What is the ice barrier?

The barrier is an ice-cliff extending from and attached to the face of a precipitous foreshore.

*** 219. Write down the names of the different forms of floating ice.**

Field ice, growlers, floe ice, hummicky ice, pack ice, drift ice, sludge ice, pancake ice, bay ice, floeberg and slob ice.

220. Distinguish between growlers, hummicky ice and a floeberg.

A *growler* is a small berg trapped in a field of ice.

Hummicky ice is formed by the pressure of the wind causing the pieces of ice in a floe to ride over each other and to pile up into hummocks.

A *floeberg* is a thick piece of salt water ice, presenting the appearance of a small iceberg.

221. Distinguish between pack ice, sludge and slob ice.

Pack ice is formed of broken up and separated pieces of ice which have closed together again. It is intersected by lanes of water which open and close, thus forming more or less navigable or unnavigable channels.

Sludge is small pieces of ice through which a ship can easily force her way.

Slob ice is the first ice to be formed, and sometimes piles up under the influence of wind and sea, and blocks harbours and bays.

222. Distinguish between floe ice, pancake ice and drift ice.

Floe ice consists of several pieces of field ice frozen together.

Pancake ice is merely frozen ice of sufficient thickness to prevent navigation, and is sometimes separated into pieces suggestive of the name.

Drift ice is unattached pieces of floating ice, and is easily navigable.

223. How may the proximity of ice be detected?

By the appearance near the horizon of an ice-blink. A warning may be given in thick weather by studying carefully the variations in the temperature of the air and sea, and by keeping a sharp look-out for the dark loom cast by a berg in a fog.

*** 224. What is an ice-blink?**

A brightening in the sky near the horizon in the direction of the ice, caused by the reflection of light from the ice. At short distances the brightness may assume the appearance of a cloud.

*** 225. What proportion of an iceberg is visible above water?**

From one-seventh to one-ninth of its bulk, depending upon the relative solidity of the submerged and visible portions.

*** 226. Where may ice be met with on the trans-Atlantic routes?**

In the neighbourhood of the Grand Bank of Newfoundland, especially north of 40° latitude, and between 40° and 60° west longitude, although bergs may drift further to the south and to the east.

See plate xxi., *Seaman's Handbook.*

*** 227. When is ice most prevalent in the North Atlantic, and describe the seasonal changes of its southern limits?**

It is most prevalent from March to August. In March the field ice extends well south to about latitude 40°, and the bergs then begin to drift to the southward of this parallel.

In July the bergs are not so numerous to the south of 40°, and become fewer as the autumn advances, and the field ice also shrinks northward during this season. In January the field ice begins to push south again and continues to do so until it reaches its maximum southern limits in March.

*** 228. State what effect the distribution of the barometrical pressure has upon the ice on the coast of Greenland.**

An area of permanent low pressure is situated to the south-eastward of the coast of Greenland, thus setting up a cyclonic circulation of wind, the prevailing direction of the wind being from north and north-east between Iceland and the coast. The current sets to the south-west in this region, so that the combined effect of the wind and current is to carry bergs and other ice along the east coast of Greenland towards Cape Farewell and the Labrador coast.

Some of these bergs may be caught in the westerly winds, which prevail further south, and be carried eastward into the Atlantic.

The northerly winds on the western segment of this low pressure area would also tend to release the ice on the west coast of Greenland and to impel it down Davis Strait into the Labrador current.

229. What causes tend to effect the quantity and distribution of ice in the North Atlantic?

The weather conditions which have prevailed over the

Arctic regions during the summer previous to the appearance of the ice, and also the strength of the Labrador current during the intervening period.

230. Why does the Labrador current have considerable influence on the ice conditions?

Because the velocity of the current varies considerably, from almost stationary up to 36 miles per day; then the volume of the current is greatly increased during spring and summer by the melting of the ice and snow of the Arctic.

231. What differences exist between Arctic and Antarctic icebergs?

The bergs of the north hemisphere are small in comparison with those of the south hemisphere, and are usually rugged and peaked. The Antarctic bergs, on the other hand, are usually flat topped and steep sided as they originally formed part of the ice barrier.

***232. What are the special features of icebergs of the south hemisphere?**

Their immense length and their great height above water. Ice islands over 1000 ft. high, and up to 20 miles in length, have been sighted when running down the easting.

233. Where is ice most frequently sighted in the Southern Ocean?

Off Cape Horn, to the eastward of the Falkland Islands, and south of 40° latitude.

234. What causes are presumed to affect the distribution and frequency of ice in the Southern Seas.

Chiefly the meteorological conditions which have prevailed over the Southern Ocean and adjoining polar regions during the previous summer, combined with the strength of the resultant polar currents.

235. What zone of the Southern Seas is freest of ice?

The zone included between 40° and 50° S. and 130° E. to 170° W. During the seven months, April to October, this area, which extends from the south coast of Australia to the east of New Zealand, is practically ice free.

236. How may bergs be broken off from the great ice barrier?

By the unequal expansion of the ice due to the great differences in temperature that sometimes exists between the mass of ice above water and the submerged portion.

The temperature of the air may be 40° to 50° below zero and the temperature of the sea 28° to 30° above.

APPENDIX I.

*** 237. What is mirage, and how is it caused?**

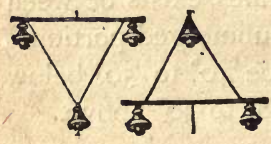
Mirage is a displacement of the horizon due to abnormal refraction and reflection of the rays of light when passing through layers of atmosphere having considerable difference of density.

APPENDIX II.

238. Describe the storm signals adopted by the Meteorological Office.

By Day.—Cone, point down, means strong winds expected from south-east to west.

Cone, point up, means strong winds expected from north-west to east.



By Night.—Three lights arranged in the form of a triangle, point downwards or point upwards to represent the south or north cone respectively.

239. Describe the code of storm signals adopted by the International Meteorological Committee.

Cone, point upward.

A gale commencing in the north-west quadrant.

Cone, point downward.

A gale commencing in the south-west quadrant.

Two cones, one above the other, both pointing upward.

A gale commencing in the north-east quadrant.

Two cones, one above the other, both pointing downward.

A gale commencing in the south-east quadrant.

Two cones with their bases together.

A hurricane.

ADDENDA.

*** 240. You are in a steamer, with wind on the port beam, situated in the right hand semi-circle of a southern hemisphere cyclone, what would you do?**

Keep going with the wind on the port beam if the weather is not too bad and the barometer rises or keeps steady, but should the barometer fall, which is an indication that the centre is approaching the ship, then keep the wind well aft on the port quarter. (*See* fig. iii., E.)

*** 241. South hemisphere, right hand semi-circle. What changes of wind and weather would you expect if the ship were kept running before the wind?**

If the wind were kept dead aft the ship's course would have to be altered from time to time as the wind changed. She would be sailing round the central area of the storm. If the wind were from, say, south-east, it would gradually veer to south and south-west and more westerly. The wind may be expected to increase in force, with violent squalls, until the trough of the storm is reached, after which the barometer would begin to rise, the wind to moderate, and the weather conditions to improve. (*See* fig. iii.)

*** 242. In the left hand semi-circle of a south hemisphere cyclone, a steamer is kept head to wind. What changes of wind and weather would be experienced?**

In order to keep the wind ahead, the ship's course would have to be altered from, say, north-east to north and north-west as the wind changed. When in the advance quadrant, the wind would likely increase in force,

with heavy squalls and falling barometer. After the trough had passed the barometer would probably begin to rise and the weather to clear up. (Fig. iii.)

***243. In the north hemisphere, hove to on the starboard tack heading north, the wind changes to north-east and you have reason to believe that a cyclone is approaching. What alteration of course would you make, if any, and why?**

If hove to on the starboard tack and heading north, the direction of the wind would be about east. If the wind then changed to north-east—a left-handed shift—the ship would be in the left hand semi-circle. Wear ship and heave to on the port tack, or run with the wind on the starboard quarter, in order to get further away from the centre. (*See* fig. ii., B, positions *1* and *2*.)

244. The wind in a revolving storm, northern hemisphere, backs from north to north-west. What is the probable bearing of the centre and what action would you take? Illustrate your answer by a diagram.

The centre bears from east to north-east.

The ship being in the left hand semi-circle (navigable) I would heave to on the port tack or run with the wind on the starboard quarter. (*See* fig. v., positions *A* and *B*.)

245. In the north hemisphere the wind in a revolving storm has veered from E.S.E. to S.S.W. What is the probable bearing of the centre and what action would you take? Illustrate your answer by a diagram.

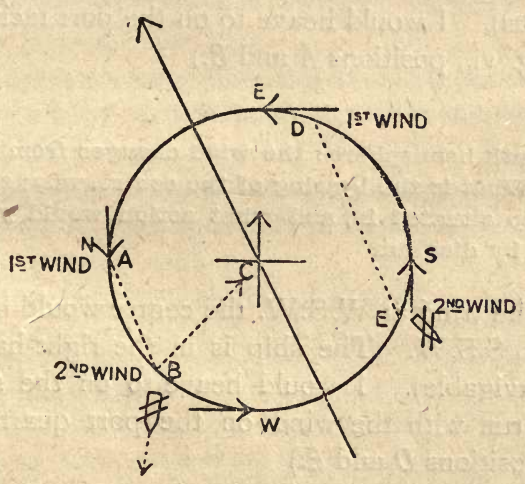
The centre would bear from N.N.W. to W.N.W., depending on the distance of the ship from the centre of the storm. The nearer the centre the more circular are the eddies of wind. The distance from the centre may be estimated roughly by the amount of fall of the

barometer. The wind having changed in a right-handed direction the ship is in the right hand semi-circle (dangerous). Heave to on the starboard tack. (*See* fig. v., positions *D* and *E*.)

In fig. v. the circle represents a circular eddy of wind, the arrows show the left-handed circulation peculiar to north hemisphere cyclones, and the letters N, W, S, E indicate the direction of the wind at the respective positions on the circle, where it is presumed to blow from the cardinal points of the compass.

A represents the position of the ship, relatively to the centre of the storm, when the wind was north, and *B* her position when the wind had changed to north-west. *B C* is the bearing of the centre from the ship, about north-east. Join *A B* by a dotted line, and draw a parallel line through the centre of the circle.

FIGURE V.



This indicates the path of the storm and shows that the cyclone is travelling to the N.N.W., the ship being on the left-hand side of the line of progression.

Similarly the dotted line from *E* to *D* indicates the direction in which the storm is travelling when the wind changes from E.S.E. to W.S.W., the ship having been hove to during the interval.

246. South hemisphere, the wind in an approaching cyclone is found to blow from E.N.E. How is the probable bearing of the centre estimated? If the wind then changes to N.N.E., on which side of the line of progression is the ship situated, and what action would you take. Illustrate by a diagram.

The approximate bearing of the centre is found by Buys Ballot's Law, allowing

12 points to the left of the wind when the storm begins.
10 ,, ,, ,, when the barometer has fallen $\frac{5}{10}$ths of an inch.
and 8 ,, ,, ,, when the barometer has fallen $\frac{6}{10}$ths of an inch or more.

Thus the centre would bear W.N.W. at first, then N.W., then N.N.W. The ship is in the left-hand semi-circle (dangerous). I would heave to on the port tack.

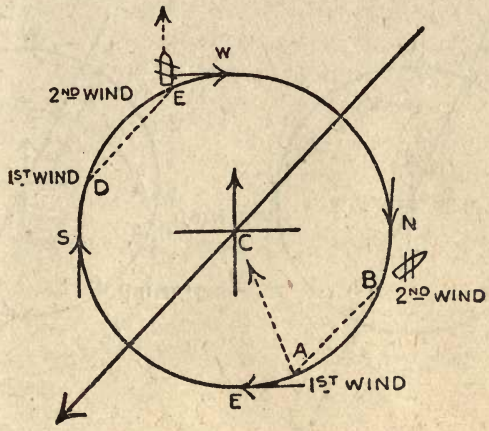
(*See* fig. vi., positions *A* and *B*.)

247. South hemisphere: the wind changes from S.S.W. to W.S.W. What is the bearing of the centre, what semi-circle is the ship situated in, and what action would you take? Illustrate by diagram.

With the wind at W.S.W. the centre would bear from E.S.E. to S.S.W. The ship is in the right-hand semi-circle (navigable). I would heave to on the starboard tack, or run with the wind on the port quarter. (*See* fig. vi., positions *D* and *E*.)

In fig. vi. the circle and arrows represent the right-handed circulation of the south hemisphere, and *A* the position of the ship in the stormfield when the wind was E.N.E., and *A C* is the line of bearing of the centre, about N.W. Spot *B* is the position of the ship when the wind was N.N.E. The dotted line *A* to *B* is the apparent track of the ship, but the direction *B* to *A* indicates the real path of the cyclone.

FIGURE VI.



Similarly the dotted line *E D* indicates the direction in which the storm is travelling when the wind changed from S.S.W. to W.S.W., as in question 247; always assuming, of course, that the ship has remained stationary.

***248. In the south hemisphere the wind changes from south to south-east, what semi-circle is the ship in and what action would you take?**

The shift of wind indicates that the ship is in the left-hand or dangerous semi-circle. I would heave to on the port tack. (*See* fig. vii.)

NOTE.—The parabolic track followed by cyclones usually has its origin a few degrees north or south of the equator and inclines towards the poles of the respective hemispheres, so that revolving storms of northern latitudes invariably travel in a northerly direction and those of southern latitudes in a southerly direction. (*See* figs. ii. and iii.)

The cyclone of this example (*see* fig. vii.) appears to be travelling to the N.N.W. an unusual direction for the south hemisphere. But this apparently retrogressive motion may be caused by the ship being actually on the right-hand side of the line of progression when travelling faster than the storm and in the same direction.

For example, *see* fig. viii., where the ship may have entered the stormfield at *A* and steamed along the dotted track from *A* to *B*, thus altering the bearing of the centre from her port bow to her port

FIGURE VII.

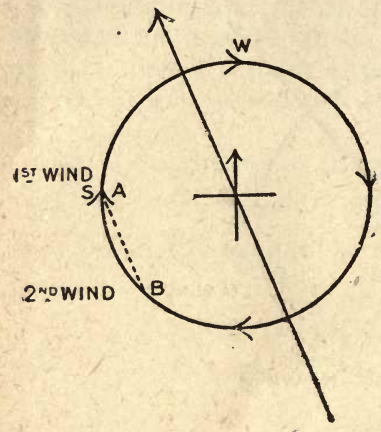
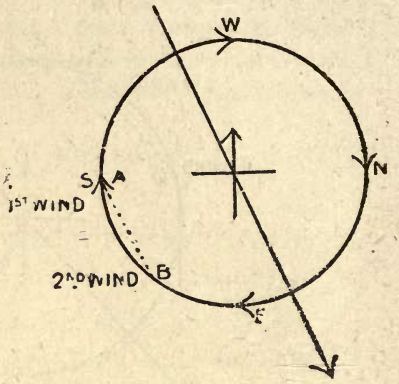


FIGURE VIII.



quarter, and at the same time altering the direction of the wind from south to south-east, a left-handed shift, yet she is in the right-hand semi-circle.

***249. In the North Atlantic, storm approaching, wind backs from south-west to south, what is the probable bearing of the centre and what would you do?** (*See* **fig. ix.**)

The shift of wind denotes that the ship is in the left-hand semi-circle (navigable). I would run with the wind on the starboard quarter or heave to on the port tack.

NOTE.—Again (*see* fig. ix.) we have a storm which appears to be travelling contrary to the direction usually followed by cyclones in the north hemisphere, and if the ship were stationary this would really be the case, as the diagram is drawn on the assumption that the ship has been hove to during the time the wind was changing from south-west to south. But suppose the storm had been moving to the north-east (fig. x.) instead of to the south-west, and the ship entered the cyclone at position *A*, she would get a south-west wind. Then, if she steamed faster than the storm and parallel to its path, that is, along the dotted line *A B*, the wind would change from south-west to south—a left-handed shift—although the ship is actually in the right-hand semi-circle.

Thus the course and speed of the ship, relatively to the progressive motion of the storm, creates an embarrassing complication when trying to estimate the ship's position in the stormfield.

FIGURE IX.

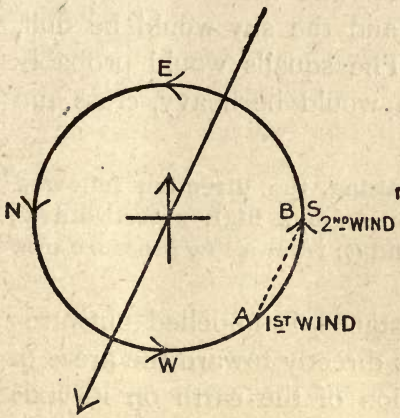
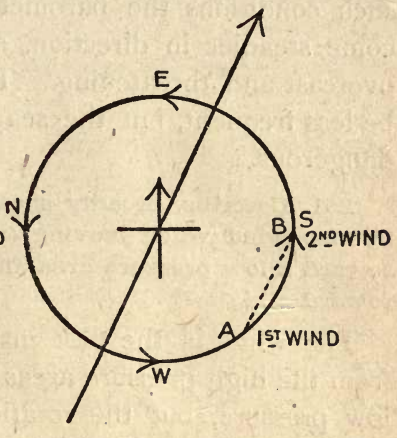


FIGURE X.



Hence the advisability of heaving the ship to when a dangerous cyclone is approaching, for then changes in the direction and in the force of the wind, as well as in the readings of the barometer, will be entirely due to the advancing of the system.

***250. In the left-hand semi-circle of a southern hemisphere cyclone, what changes of wind and weather would you experience by keeping the wind on the port quarter?**

In order to keep the wind at the same angle on the port quarter the ship's course would have to be altered whenever the wind changed in direction. The ship would be heading away from the centre but the change of wind and weather would depend greatly on the relative speeds of the ship and storm; on whether the centre was approaching the ship or the ship getting away from the low barometer.

Assuming the exceptional case of the cyclone being stationary, and the wind experienced was, say, from north, then as the ship proceeded in a S.E. direction the wind would change to N.E. and more easterly, the ship's course meanwhile having to be altered to starboard, and so causing her to perform a spiral track round the centre,

but gradually moving away from the central area. Under such conditions the barometer and the wind would become steadier in direction, and the sky would be dull, overcast and threatening. The squalls would probably be less frequent, but the sea would be heavy, cross and dangerous.

***251. Describe, broadly speaking, the direction followed by the wind when moving (*a*) from a high pressure area toward a low pressure area and (*b*) from a low pressure area toward a high.**

The wind, in the first instance, is impelled outwards from the high pressure areas directly toward the areas of low pressure, but the rotation of the earth on its axis causes a current of air to be deflected to the right-hand in the north hemisphere and to the left-hand in the south hemisphere.

Thus in (*a*) the current of air will be deflected to the right-hand when it leaves the area of high pressure and will acquire an outward, circular motion round the centre of the system, clockwise in the north hemisphere and anti-clockwise in the south hemisphere (anti-cyclonic system.)

(*b*) When the current of air comes within the influence of the low pressure area it seeks towards the centre of the depression and acquires a circular motion round the area of low pressure, the direction of incurvature being anti-clockwise in the north hemisphere and clockwise in the south hemisphere (cyclonic system.)

***252. What is meant by dry air, and what is the weight of a cubic foot of air at the sea level?**

Dry air is an artificial atmosphere, composed chiefly of nitrogen and oxygen, and contains no water vapour. It is represented by the figure 0 on the percentage scale of relative humidity.

A cubic foot of air at sea level weighs 500 grains.

***253. Why is a current of air deflected to the right-hand in the north hemisphere and to left hand in the south hemisphere?**

Because places in different latitudes are rotated by the earth at different speeds.

The earth's surface and the surrounding atmosphere at the equator is carried to the eastward at the rate of 900 miles per hour, in 60° latitude at 450 miles per hour, the speed gradually decreasing to zero at the poles.

Imagine a current of air impelled from the equator directly towards the poles. In addition to flowing along the meridians it will start off with a velocity of 900 miles per hour to the eastward, which at first is not apparent, as the observer on the earth's surface is being carried round at the same speed. But on proceeding poleward, the current of air arrives, successively, at places having a slower and slower speed of rotation, with the result that owing to the initial velocity imparted to it at the equator, the air current is rotated faster than an observer on the earth's surface, and is consequently impressed with an easterly motion, flowing to the N.E. in the north hemisphere, and to the S.E. in the south hemisphere.

If the earth did not rotate in its axis, a current of air when flowing from the poles to the equator, would flow due south in the north hemisphere and due north in the south hemisphere. Now, start the earth rotating and imagine an observer facing east. He will be carried forward into this side wind. The apparent effect will be the same as if a ship were steaming east with a beam wind, when the current of air would appear to come from the port bow if the wind were northerly, or from the starboard bow if the wind were southerly. In other words, a current of air is deflected to the right when north of the equator and to the left when south of the equator. This is partly the explanation of N.E. and S.E. trades.—Study this out quietly.

QUESTIONS ON METEOROLOGY.

Similar to those already set at the Board of Trade Examinations, arranged in the order of the chapters:—

Barometer Manual.

CHAPTER I., AND APPENDIX I.

For an answer refer to question No.

1. Describe the mercurial barometer and the principle of its working.

10. What corrections do you apply to the barometer, and how are they applied?

18. Describe a barograph, how it is regulated, and what corrections are required.

19. Describe the principle of the thermometer, and the scales you know.

8. What is the pressure of the atmosphere at sea level?

CHAPTER II.

38. Name the five great areas the earth's surface is divided into with regard to barometrical pressure.

43. What causes the trade winds?

40. What sort of weather is experienced between the N.E. and S.E. trades, and why?

CHAPTER III.

45. Explain what is meant by the terms periodical and non-periodical barometrical pressure.

46. When should the mean barometrical pressure be recorded in the tropics and why?

46, 99. Describe the diurnal range of the barometer in tropical and sub-tropical regions. What would be the effect of its cessation?

50a. What governs the diurnal range of the barometer and the times of the maximum and minimum readings?

CHAPTER IV.

55. What is the origin of the term cyclone?

56. What are the chief differences between a cyclonic and an anti cyclonic system?

52. What is the standard adopted in the British Isles for estimating the barometrical gradient?

53. What influence has the rotation of the earth on a current of air passing from an area of relatively high pressure to one of relatively low pressure?

58. Does the wind follow the isobars?

57. Give Buys Ballot's Law.

51, 138. What is meant by the term "pressure gradient," and how is it related to the force of the wind?

CHAPTER VI.

93. What is the most favourable geographical condition for a tropical cyclone?

96. If in the vicinity of a revolving storm how would you find approximately where the centre was situated and its path?

96. What are the two principal points a seaman should know on the approach of a cyclone, and how are they determined?

98. Which are the dangerous and navigable semi-circles of a tropical cyclone, and give reasons?

94. What areas do revolving storms extend over, and give their speeds?

99. What are the usual indications of the approach of a cyclone?

Figs. ii. and iii. Draw a diagram showing the average paths followed by tropical cyclones when advancing into the temperate zones, and show the direction of the wind in the storm field.

96. State Buys Ballot's Law and show by a diagram its application to an approaching cyclone.

104. In a cyclone, north hemisphere, right hand semi-circle, what action would you take?

105. Northern hemisphere cyclone, in the left hand semi-circle, what would you do and why?

102. On the line of progression of a West India hurricane and no room to run, what would you do, and explain your reasons?

243. North hemisphere, hove to on starboard tack heading north, the wind changes to N.E. and you have reason to believe that a cyclone is approaching, what alteration of course would you make, if any, and why?

249. North Atlantic, storm approaching and wind backs from S.W. to S. What would you do and what is the probable bearing of the centre?

103. South hemisphere, your ship is on the track of an advancing cyclone, what is the most prudent course to take?

106. South hemisphere, left hand semi-circle, wind on starboard beam, what alteration of course would you make, if any?

240. South hemisphere, in a steamer, wind on port beam in the right hand semi-circle, what would you do?

109. South hemisphere, left hand semi-circle, you run keeping the wind on the starboard quarter, what changes of wind and weather would you experience?

107. South hemisphere, strong trade wind increasing in force, what would you do?

108. In the Indian Ocean, north-east gale and falling barometer, what precautions would you take?

241. South hemisphere, right hand semi-circle, what changes of wind and weather would you expect if the ship were kept running before the wind?

242. South hemisphere, left hand semi-circle, a steamer is kept head to wind, what changes of wind and weather would be experienced.

250. South hemisphere, left hand semi-circle, what change of wind and weather would you experience by keeping the wind on the port quarter?

248. South hemisphere, wind changes from S. to S.E., what semi-circle is the ship in and what action would you take?

114. Describe the cyclones of the Bay of Bengal and name the seasons when they are most frequent.

110. Describe the track of a hurricane in the North Atlantic and give the seasons.

111. Describe the cyclones of the Indian Ocean, their track and seasons.

113. Describe the typhoons of the China Sea, where they originate, their track and season.

112. Describe fully the track of a cyclone in the South Pacific, where do they originate, and in what months are they most frequent?

114. Describe the track of cyclones in the Arabian Sea and give the seasons when they most frequently occur.

Seaman's Handbook on Meteorology.

CHAPTER I.

115. Name the gases composing the atmosphere and average percentage per volume.

115. What height is the atmosphere above the earth's surface and what experiments have been made to prove this?

117. What are the principal causes of wind?

53. What influence has the rotation of the earth on a current of air passing from an area of relatively high pressure to an area of relatively low pressure?

251. Describe, broadly speaking, the direction followed by the wind when moving from (*a*) a high pressure area surrounded by a low pressure area and (*b*) from a low pressure area surrounded by a high.

55. What is the origin of the term cyclone?

118. What is the effect of difference of temperature in adjacent localities on the equilibrium of the atmosphere?

8. What is the pressure of the atmosphere at the sea level and how is the pressure exerted?

117. What is wind and how does it derive its energy?

CHAPTER II.

121. Under what circumstances are the sun's rays hottest, and state your reason?

124. Describe the atmosphere which causes terrestrial radiation and retards terrestrial radiation.

123. Describe terrestrial radiation and its effect on the temperature of the earth's surface.

127. What is the range of temperature in the British Isles?

125. Why is the climate more equable and milder on the seaboard than inland?

127. Name the seasons in the temperate zone as defined by the march of temperature. Give the dates of the highest and lowest mean daily temperature, also the temperatures.

125. Why is the temperature range less in the British Isles than on the continent?

130. What is aqueous vapour, how is it caused, and what form does it take when leaving the water?

130. From whence and how does the atmosphere derive its moisture?

126. How does the temperature of the air vary, and why?

128. What are isotherms, and why are they so called?

136. What is meant by relative humidity?

133. Describe fully how rain is formed.

134. What is meant by latent heat?

252. What is meant by dry air, and what is the weight of a cubic foot of air at the sea level?

131. What is meant by vaporisation?

136 and 252. What is dry air, saturated air and relative humidity?

CHAPTER III.

52. What standard is adopted in the British Isles for estimating the barometrical gradient?

141. Is the actual wind velocity greater or less than the theoretical velocity as deduced from the gradient? State your reasons.

137. Does the wind follow the isobars?

51 and **138.** What is meant by the term "pressure gradient," and how is it related to the force of the wind?

CHAPTER IV.

142. Describe clearly how clouds are formed.

142. What are clouds and what are they composed of?

145. Describe cirrus clouds.

151. Describe strato-cumulus clouds.

149. Describe cirro-cumulus clouds.

142 to **152.** Name the standard types of clouds as classified by the International Committee.

157. What weather would an observer experience if situated on the southern side of the path of a cyclonic system near the United Kingdom during its passage?

CHAPTER V.

161. How is sea fog formed?

168. Why is there more rain on the polar side of a cyclone than on the equatorial side?

CHAPTER VI.

185. What is a gust and what is a squall, and what causes them?

183. What is a "V" shaped depression?

182. Describe a secondary wind system.

188. What is a line squall?

CHAPTER VII.

189. What are the indications of an approaching storm before the barometer starts to fall?

199. How is dew formed, and what conditions of the atmosphere are most favourable to its formation?

189. How could you tell before the barometer begins to fall, or the wind becomes unsteady, that a cyclonic disturbance was approaching?

CHAPTER X.

226 and **227.** Where is ice met with in the North Atlantic, and when is it most prevalent?

219. Name the different kinds of floating ice.

224. What is an ice blink?

222. What is floe ice, and how is it formed?

—— What is field ice, and how is it formed?

217. Describe the formation of icebergs.

225. How much of an iceberg is immersed, and how is the quantity arrived at?

232. Describe the principal features of icebergs in the southern hemisphere.

228. State what effect the distribution of the barometrical pressure has upon the ice on the coast of Greenland.

Papers on Meteorology as set at the Board of Trade Examinations.

PAPER I.

For an answer refer to question No.

117. What are the principal causes of wind?

125. Why is the climate more equable and milder on the seaboard than inland?

52. What standard is adopted in the British Isles for estimating the barometrical gradient?

226 and **227.** Where is ice met with in the North Atlantic and when is it most prevalent?

109. In the left hand semi-circle of a southern hemisphere cyclone you run with the wind on the starboard quarter, what changes of wind and weather would you experience?

110. Describe the track of a hurricane in the North Atlantic and give the seasons when they are most frequent.

PAPER II.

53. What influence has the rotation of the earth on a current of air passing from an area of relatively high pressure to one of relatively low pressure?

134. What happens to the heat used in changing water into vapour?

151. Describe strato-cumulus clouds.

157. What weather would an observer experience if situated on the southern side of the path of a cyclone system near the United Kingdom during its passage?

40. What sort of weather is experienced between the north-east and south-east trades, and why?

96. In the vicinity of a revolving storm, how would you find approximately where the centre was situated and its path?

PAPER III.

127. Name the seasons in the temperate zone as defined by the march of temperature. Give the dates of the highest and lowest mean daily temperature, also the temperature.

219. Name the different kinds of floating ice.

38. Name the five great areas the earth's surface is divided into with regard to barometrical pressure.

43. What causes the trade winds?

99. What are the usual indications of the approach of a revolving storm?

103. Your ship is in the track of a cyclone in the southern hemisphere, what is the most prudent course to take?

PAPER IV.

224. What is an ice blink?

125. Why is the temperature range less in the British Isles than on the continent?

130. What is aqueous vapour, how is it caused, and what form does it take when leaving the water?

188. What is a line squall?

94. Give the areas covered by revolving storms, and their speeds.

96. What are the two principal points a seaman should know on the approach of a cyclone, and how are they determined?

PAPER V.

115. Name the gases composing the atmosphere and average percentage per volume.

182. Describe secondary wind systems.

121. Under what circumstances are the sun's rays hottest, and for what reason?

141. Is the actual wind velocity greater or less than the theoretical velocity, as deduced from the gradient? State your reasons.

98. Which are the dangerous and navigable semi-circles of a tropical cyclone, and give reasons for naming them?

106. You have reason to believe you are in a tropical cylone, south hemisphere, left hand semi-circle, wind on starboard beam, what alteration of course would you make, if any?

PAPER VI.

124. Describe the atmosphere which accelerates terrestrial radiation and which retards radiation.

145. Describe cirrus clouds.

185. What is a gust, and what is a squall, and what causes them?

232. Describe the principal features of icebergs in the southern hemisphere.

104. You have reason to believe you are in the right hand semi-circle of a cyclone in the northern hemisphere, what action would you take?

112. Describe fully the track of cyclones in the South Pacific. Where do they originate, and in what months are they most frequent?

PAPER VII.

118. What is the effect of difference of temperature on adjacent localities on the equilibrium of the atmosphere?

142. Describe clearly how clouds are formed.

45. What do you understand by the terms periodical and non-periodical barometrical pressure?

10. What corrections do you apply to the barometer, and how are they applied?

102. Suppose you are on the line of progression of a West India hurricane and no room to run, what would you do, and explain your reasons?

112. Describe the track and give the seasons of cyclones in the South Pacific.

PAPER VIII.

115. What height is the atmosphere above the earth's surface, and what experiments have been made to prove this?

123. Describe terrestrial radiation and its effect on the temperature of the earth's surface.

142, 183. What are clouds and what are they composed of? What is a "V" shaped depression?

105. North hemisphere, in the left hand semi-circle of a revolving storm, what would you do, and give reasons?

111. Describe the Indian Ocean cyclone, and give the seasons when they most frequently occur.

PAPER IX.

55. What is the orgin of the term cyclone?

168. Why is there more rain on the polar side of a cyclone than on the equatorial side?

19. Describe the principal and construction of the thermometer and the scales you know.

237. Describe what produces mirage.

107. South hemisphere, strong trade wind and increasing in force, what would you do?

114. Describe the track of cyclones in the Bay of Bengal, and give the seasons.

PAPER X.

130. What is aqueous vapour?

127. What is the range of temperature in the British Isles?

149. Describe cirro-cumulus clouds.

1. Describe the mercurial barometer and the principle of its work.

103. South hemisphere—on the line of progression of a cyclone—what would you do?

113. Describe the track of cyclones in the China Seas, give the seasons, and state where they originate.

PAPER XI.

58. Does the wind follow the isobars?

142 and 152. Name the standard types of clouds as classified by the International Committee, and give abbreviations.

46. When should the mean barometrical pressure be recorded in the tropics?

57. State Buys Ballot's Law.

108. North-east gale, Indian Ocean, falling barometer, what precautions would you take?

114. Describe the track and give the seasons of cyclones in the Arabian Sea.

PAPER XII.

8. What is the pressure of the atmosphere at the sea level?

130. From whence and how does the atmosphere derive its moisture?

189. What are the indications of an approaching storm before the barometer starts to fall?

149. Describe cirro-cumulus clouds.

243. Northern hemisphere, hove to on starboard tack heading north, the wind changes to north-east and you have reason to believe that a cyclone is approaching, what alteration of course would you make, if any, and why?

111. Describe the Indian Ocean cyclone and give seasons.

PAPER XIII.

8. What is the average pressure of the atmosphere at the earth's surface? How is the pressure exerted?

128. What is an isotherm, and why are they so-called?

—— Describe alto-stratus.

—— What is field ice and how is it formed?

Figs. ii. and iii. Draw a diagram showing the average paths of tropical storms when moving into the temperate zones and the direction of the wind in the storm field.

240. You are in a steamer with wind on the port beam, situated in the right hand semi-circle of a southern hemisphere cyclone, what would you do?

PAPER XIV.

117. What is wind and how does it derive its energy?

131. What is meant by vaporisation?

96. Give Buys Ballot's Law and its application to an approaching cyclone, with diagram.

217. Describe the formation of icebergs.

111. Indian Ocean cyclones, give their track and season.

250. In the left hand semi-circle of a southern hemisphere cyclone, what changes of wind and weather would you experience by keeping the wind on the port quarter?

PAPER XV.

56. Define the terms cyclonic and anti-cyclonic.

199. Describe the atmospheric conditions most favourable to the formation of dew, also the process of formation.

161. Describe how sea fog is formed.

98. Which are the navigable and dangerous semi-circles of a tropical cyclone, and why are they so called?

50a. What governs the diurnal range of the barometer and the times of the maximum and minimum readings?

249. In the North Atlantic, storm approaching, wind backs from south-west to south, what is the probable bearing of the centre and what would you do?

PAPER XVI.

252 and **136.** What is dry air, saturated air and relative humidity?

146. Describe cumulus.

16. Describe the aneroid barometer.

189. How could you tell before the barometer begins to fall or the wind becomes unsteady that a cyclonic disturbance was approaching?

251. Describe, broadly speaking, the direction followed by the wind when moving (*a*) from a high pressure area surrounded by a low pressure area and (*b*) from a low pressure area surrounded by a high.

248. In the south hemisphere the wind changes from south to south-east, what semi-circle is the ship in and what action would you take?

PAPER XVII.

252. What is meant by "dry air," and what is the weight of a cubic foot of air at sea level?

138, 51. What is meant by the term "pressure gradient," and how is it related to the force of the wind?

93. What are the most favourable geographical conditions for a tropical cyclone?

134. What is meant by "latent heat"?

225. How much of an iceberg is immersed, and how do they arrive at the quantity?

243. Hove to on starboard tack in the north hemisphere, and you have reason to believe that a cyclone is approaching. The wind changes to north-east, what alteration of course would you make, if any, and why?

PAPER XVIII.

228. State what effect the distribution of barometrical pressure has upon the ice on the Coast of Greenland.

126. How does the temperature of the air vary, and why?

115. How does the density of the air vary, and why?

150. Describe cirro stratus.

113. Describe the cyclones in the China Sea, where they originate, their track and season.

242. South hemisphere cyclone in the left hand semi-circle, a steamer is kept head to wind, what changes of wind and weather would you experience?

PAPER XIX.

53, 253. What effect has the earth's rotation on a current of air (*a*) in moving from a lower to a higher latitude; (*b*) from a higher to a lower latitude, and state you reasons?

136. What is meant by relative humidity?

133. What causes rain, and give your reasons?

18. Describe a barograph, how it is regulated, and what corrections are required.

46, 99. Describe the diurnal range of the barometer in tropical and sub-tropical regions. What would be the effect of its cessation?

241. In the right hand semi-circle of a southern hemisphere cyclone, the ship is kept head to wind. What changes of wind and weather would you expect, and why?

PAPER XX.

***216.** What is a glacier, and what happens to it in temperate and tropic zones?

124. How does change of temperature and wind effect evaporation?

— What precautions would you take in harbour if there are indications of an approaching cyclone?

148. Describe nimbus cloud.

117. What causes difference of pressure in adjacent localities?

113. Describe the cyclones of the China Sea, and give their track and seasons.

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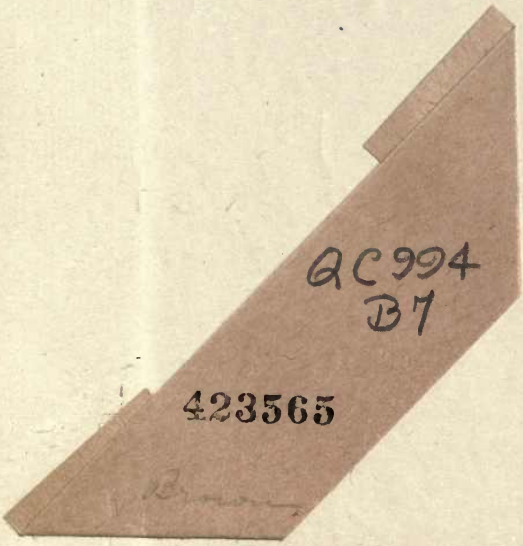
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